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NOVEMBER, 1904.

THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCE.

BY WM. HARPER DAVIS,
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THE first International Congress of Arts and Science has passed honorably into history. What may have been a philosopher's dream is now also a fact accomplished. Not that with the successful completion of the program the living influence of the congress has ceased. Rather, indeed, is it certain to continue and possibly to yield increase beyond foretelling. This is really implied in the statement that the undertaking was a success, as must appear to all who are cognizant of the unique purpose and the correspondingly definite plan of the whole. With this our readers may be assumed to be in a general way familiar. In this article some attempt will be made to sketch, unhappily in an all too fragmentary fashion, the actual operation and course of the congress and to indicate, in a manner necessarily inadequate, a few tentative impressions as to its outcome and probable value. No single man, least of all one who had the pleasure of attending the congress in blissful ignorance of the reporter's task which was in store for him, can hope to do justice to a program so vast and so varied as was that which filled the week from the nineteenth to the twenty-fifth of September last at St. Louis.

The great exposition now in progress is notable not only for its material illustration of the arts and industries of the world, but chiefly because in its conception the place of first importance has been given to education. This means the explicit acknowledgment of the sovereignty of mind in human progress to a degree unprecedented in similar undertakings. It was therefore peculiarly fitting that the management should make a special effort to assemble a congress of the world's leaders in the acquisition, elaboration and application of knowledge, as a worthy spiritual capstone to the magnificent material edifice

PROFESSOR WILHELM WALDEYER, of the University of Berlin, Honorary Vice-president of the Congress for Germany, who gave the address on Human Anatomy. The portraits illustrating this article were taken for THE POPULAR SCIENCE MONTHLY by Mrs. Jessie Tarbox Beals, Press Photographer, St. Louis, Mo.

which their enterprise had erected. Imposing as is the mere array of the visible tokens of progress in material civilization—a progress born of science, nourished by science, and in its turn begetting science—the whole must appear considerably more impressive when seen to be, as it really is, the outer expression of the inner intellectual life of mankind, the index of its vigor and plenitude, and the earnest of its future possibilities. Almost all the departmental exhibits, including manufactures, machinery, electricity, transportation, agriculture, horticulture, forestry, mines and metallurgy, and the like, illustrate directly the progress of applied science, while all, without exception, depend for their existence upon its development. Government and social economy presuppose some kind of philosophy and even a certain amount of knowledge, and both will increasingly apply the methods and results of science. Even the fine arts, quite apart from their technique, appeal to the reason and depend upon criticism. Some of the exhibits

were strictly in pure science, as *e. g.*, the department of anthropology, which included a laboratory of anthropometry and psychometry.

Such considerations suggest the ideal advantage which the Congress of Arts and Science enjoyed through its relation to the great exposition. It would further seem a happy thought which led to the convocation of an international group of scholars at a place independently dedicated as a meeting ground of the nations. Not to mention other advantages of a more practical kind for such of the participants as were interested in seeing a great world's fair, or studying some special aspect of its exhibition, the provision for this congress was at once a tribute to science many times deserved, and especially a lesson to the public at large of incalculable educational value. Besides, here was an opportunity too rare to be despised, of realizing, however imperfectly, a worthy ambition, widely shared, for the internal improvement of the whole kingdom of knowledge.

On the other hand, there were obvious drawbacks to the satisfactory conduct of meetings for the serious discussion of abstract and learned subjects under the conditions presented by a world's fair. It was impossible for the committee to overcome all the difficulties incidental to the subordination of the congress to the management of the exposition, of which it was externally but a small part, however significant. The fair's department of congresses had to provide for at least one hundred and fifty special conventions or international congresses of one kind or another, besides this universal congress. It was unfortunate that more halls suitable for speaking and hearing, and less widely scattered, could not be found or spared, and that no proper waiting and lounging room was provided for social intercourse. Yet great scholars spoke cheerfully to attentive listeners and congenial spirits contrived to meet for friendly conversation or for seeing the fair together. If some of the foreign guests suffered temporary inconvenience on the score of the creature comforts, they will probably not long remember it against us.

Those acquainted with the conditions may well pause for wonder at the smoothness with which so complicated a piece of machinery was kept running, involving as it did the direction of so large and variegated a group of markedly individual men who were for the most part hurried. In this connection credit is especially due the energy, patience and industry of the faithful staff of executive assistants under the efficient direction of the executive secretary of the congress, Dr. L. O. Howard, of Washington, government entomologist and chief of the division of entomology, U. S. department of agriculture. The congress was fortunate in securing for this arduous work the services of so eminent a worker for science, both as an investigator and as the permanent secretary of the American Association for the Advancement of Science, with his able assistant, Mr. Clifton. It is significant of the spirit of the congress that Dr. Howard's special executive assist-

ants were six doctors of philosophy engaged in university teaching, who also served as secretaries for their special sectional meetings.

This was a congress of scholars, conceived, administered and conducted by scholars. Under the general supervision of Dr. Howard J. Rogers, deputy superintendent of education for the state of New York, who was the official director of congresses for the exposition, it was arranged by an administrative board consisting of Presidents Harper of Chicago, Jesse of Missouri, Pritchett of the Massachusetts Institute of Technology, Librarian of Congress Putnam and Director Skiff of the Field Columbian Museum, under the chairmanship of President Butler of Columbia University, a professor of philosophy and a distinguished expert in education.

The congress was presided over by Simon Newcomb, retired professor in the United States Navy, a profoundly original, accomplished and productive astronomer and mathematician, perhaps of all Americans the most honored throughout the world among the peers of the realm of science. Hugo Münsterberg, Harvard's brilliant psychologist, philosopher and man of letters, author of the original plan of the congress, to whom is also due the largest share of credit for the splendid achievement, divided the vice-presidency with Albion W. Small, professor of sociology in the University of Chicago, whose wide grasp of the multifarious activities of organized social regulation and culture is largely responsible for their elaborate representation in the final scheme.

Thanks to the wisdom, enthusiasm and devotion of these learned officers of the congress, and the intelligent enterprise of the management of the exposition under its president, the Hon. David R. Francis, it was possible to carry out a program without a parallel in history. Other meetings of men, including some more eminent than any of those who came to St. Louis, may have accomplished more for science and civilization, but never before has there been a gathering of so large and representative a body of the world's leading scholars and thinkers. It will be sufficient to remind our readers in passing that the unique purpose of this congress was to see science whole. It was a deliberate attempt to exhibit the totality of intellectual achievement, to formulate the interrelations of the several branches of knowledge, and in some measure to realize the potential unity of the several sciences and their applications by harmonizing the confused mass of knowledge scattered through a bewildering multiplicity of specialties.

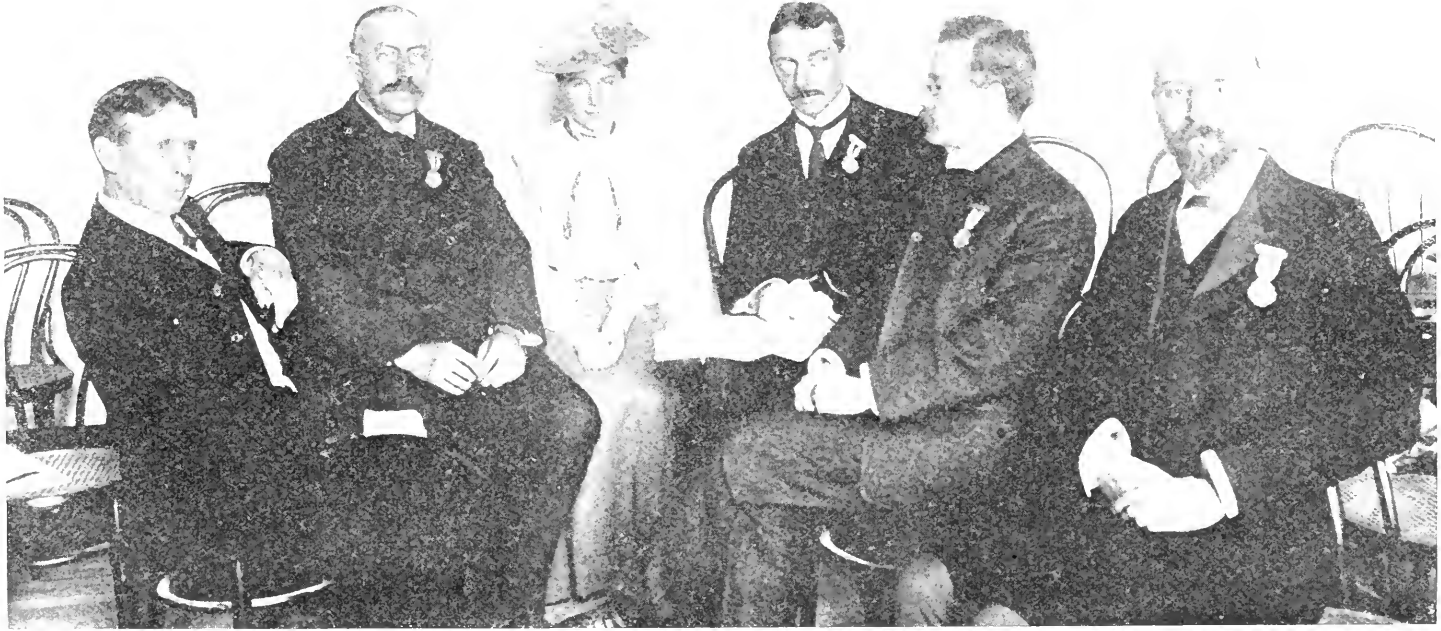
The program was designed to exhibit a certain dramatic unity in the order of the proceedings, which represented a progressive differentiation from the most general treatment of knowledge in the opening session through the several divisional and departmental addresses to the more specialistic sectional discussions, with a view to effecting an ultimate integration within each group, from the particular sections up to the all-inclusive whole of knowledge. The manner of the actual acting out of this ambitious plot during that memorable week in Sep-

tember must now be sketched in broad outlines and the details of the performance indicated by the barest reference to a few cases which may be taken as typical. Here the writer, lacking an adequate grasp of the whole, must be limited for illustration to the parts of the program with which he happens to be somewhat familiar.

Most of the members of the congress reached St. Louis on the morning of Monday, the nineteenth, registering in the exposition's Hall of Congresses, reserved as the official headquarters. The foreign guests were largely accommodated within the grounds in the dormitories of Washington University. The expenses of all the principal

PICARD. MOORE. MASCHKE.

Professor E. H. Moore of the University of Chicago presided, and M. Emile Picard of the Sorbonne and Professor H. Maschke of the University of Chicago gave the Addresses before the Section of Algebra and Analysis.



CLARKE. JORDAN. OSBORN. SCOTT. WOODWARD.

Officers of the Section of Paleontology and President David Starr Jordan, who gave the address on the Utilitarian Sciences. The addresses on Paleontology were given by Professor Henry F. Osborn, of Columbia University, and Dr. A. S. Woodward, of the British Museum. Professor W. B. Scott, of Princeton University, was Chairman and Dr. John M Clarke, Geologist of the State of New York, was Secretary of the Section.

speakers were liberally paid and each had been asked to prepare an address on a prescribed topic having a definite place in the total scheme.

The officers and speakers numbered over 500, while the total registration was about 2,000. Many probably attended meetings and enjoyed the privileges of the congress without registering as regular participants. Almost all the leading colleges, universities and higher institutions of learning at home and abroad were represented, although about 125 officers and speakers were scholars not engaged in university teaching. These include museum curators, experts in government scientific bureaus, representatives of research institutions, observatories, the army and navy, legislative bodies and diplomatic embassies, besides eminent municipal officers, school administrators, editors, librarians, engineers, architects, artists, physicians, social workers, clergymen, lawyers and jurists.

About 90 of the speakers were foreign scholars, of whom perhaps 60 addressed the congress in their own languages—German, French, Italian or even Dutch.

Counting the Mexican and the half dozen Canadians for America, there remain about 25 from Great Britain, over 30 from Germany, almost 20 from France, a half dozen from Austria, about as many from Italy, at least 4 from Japan, one from Russia, and about 10 representing other countries—Holland, Belgium, Denmark, Sweden, Switzerland and Hungary. The Americans came from all parts of the country, a meritorious group of scholars worthy to receive their eminent guests from abroad. No less than seven women, distinguished for scholarship, were among the Americans who addressed the congress.

It was indeed a notable audience of men and women which assembled in the great Festival Hall of the exposition for the formal opening on Monday afternoon. Here under one roof were seated hundreds of scholars brought together by the common interests of learning and research, come together to exchange ideas and to meet and hear their peers and leaders. On the platform sat the administrative officers of the congress, the president and vice-presidents, and a distinguished group of representative leaders in the science of foreign countries, who had been invited to act as honorary vice-presidents of the congress. The meeting was called to order by Director Rogers, who called upon President Francis of the exposition to preside over the preliminary part of the session. In an appropriate address of welcome the congress was declared by President Francis to be the crowning feature of the exposition. An address was then made by Director Skiff, in charge of the exhibits of the exposition, on behalf of the administrative board, in which the exposition was characterized as a world's university, the exhibits being its museum and laboratories, and the participants of the congress its faculty. In the regretted absence of President Butler, made necessary by serious illness in his family, President Harper made a suitable address, setting forth the history of the plan and the prepa-

rations for the work of the congress. Responses followed by the honorary vice-presidents. England was represented, in the absence of Mr. Bryce, by Sir William Ramsay, K.C.B., professor in the Royal Institution of London, who stands in the forefront among inorganic chemists, distinguished by his discovery of argon and several other new chemical elements. M. Gaston Darboux, perpetual secretary of the Paris Academy of Sciences, one of the most original and profound inquirers in the field of modern geometry, spoke for France in the French language. Germany's spokesman was the venerable and venerated anatomist, the eminent Professor Wilhelm Waldeyer of the University of Berlin, who spoke in the language in which he has addressed two generations of medical students who have become leaders in the science of their profession. Dr. Oskar Backlund, director of the Russian Observatory at Pulkowa, which he has made famous by his celebrated astronomical measurements, expressed the greetings of Russia in English. Professor Theodor Escherich, the renowned Viennese pediatrician, spoke in German on behalf of Austria. Senior Attilio Brunialti, member of parliament and councilor of state at Rome, eminent student of constitutional law, which he came to discuss before the congress under the department of jurisprudence, after a few preliminary words in English, broke into his own familiar tongue in order, as he explained, to do justice to the feelings by which he was moved. The demonstrative enthusiasm of his expression was reciprocated by the hearty applause of the audience. In this succession of striking addresses by eminent personages, so individual and at the same time so representative, the keynote of the congress was struck and the spirit which animated the whole was quickly caught.

The scientific part of the program was then set going by the introductory address of the president of the congress, Professor Newcomb, who sketched in a scholarly and illuminating manner the evolution of the scientific investigator, who must be regarded as 'the primary agent in the movement which has elevated man to the masterful position he now occupies.' The common motives of all research and the vital significance of all truth for civilization and human welfare, as brought out in this address, seemed at once to suggest and to justify the universal scope and synthetic purpose of the congress, which was to comprehend not only all the branches of theoretic knowledge, but their several applications to the arts of life.

On Tuesday morning the seven grand divisions of the congress convened simultaneously, each division being addressed by an American scholar, chosen because of a conspicuous breadth of grasp in a wide domain of inquiry and an authoritative appreciation of its inner unity.

Thus normative science, inclusive of philosophy and mathematics in their entirety, was discussed by Professor Josiah Royce of Harvard University, America's foremost representative of speculative philosophy, unrivaled in systematic and constructive learning, unexceled in subtlety

of insight, who has awakened a fruitful interest in mathematics among philosophers and in philosophy among mathematicians.

In a remarkable address, too technical to summarize here, in which, to the luminous exposition of old ideas, was added the suggestion of novel ideas of fundamental interest, a statement was made of the community of interest shared by the several philosophical and mathematical sciences when abstractly regarded, and an account given of certain concrete investigations typical of the contemporary mutuality of interest among the more advanced students of philosophy and mathematics, together with some promising results. The sciences here grouped together as normative all agree in that they seek 'ideal' truth, as distinct from physical truth or from historical fact—are concerned with the consequences, implications and interrelations of ideas or of ideals, rather than with the order of phenomena or events. The mathematician is concerned with the exact expression and abstract logical development of ideas, the meaning of which in terms of their ultimate relations is sought by the philosopher. Both groups of sciences in all their branches are in need of a theory of the 'categories' or the fundamental and logically elementary conceptions by means of which human minds think; and in the discovery of such categories and their critical classification students in both groups must cooperate.

The discussions under physical science, embracing not only physics, chemistry, astronomy and the sciences of the earth, but biology and anthropology as well, were heralded by Dr. Robert S. Woodward, professor of mechanics and dean of the school of pure science at Columbia, distinguished alike for his buoyant efficiency and for his skillful command of the mathematics as a tool of physical inquiry, in which he combines a conspicuous catholicity in scholarship with a rare versatility in research, having been especially successful in the treatment of problems in cosmical mechanics which overlap the borders of many sciences. Professor Woodward pointed out a threefold unity in all physical science—a unity of origin in observation and experiment, a unity of growth in quantitative expression and elaboration toward prediction as a goal, and a unity of purpose in its attempt to describe the universe in 'consistent and verifiable terms.' A culminating unity, linking physical science to all other science, may be found in the light which it throws on man, and the human ends which it fulfills.

The unity and variety of historical science, comprising political and economic history, and the histories of law, language, literature, art and religion, was discussed with characteristic literary distinction by Woodrow Wilson, president of Princeton University, widely known as an historical student of politics, a literary student of history, an engaging cultivator of literature and a fond admirer of all the humanities. The conditions requisite to a needed synthesis both in the teaching and the writing of history were pointed out, with special emphasis upon the services of literary art and the conceiving imagination. The

ROTCH. ARRHENIUS. NIPHER. CLAYTON. BAUER.

After the Adjournment of the Section of Cosmical Physics. The Addresses were given by Professor Svante Arrhenius, of the University of Stockholm, and Dr. A. L. Rotch, Director of the Blue Hill Meteorological Observatory. Dr. L. A. Bauer, of Washington, was Secretary.

historian of religion was said to be especially concerned with the workings of an incalculable supernatural factor, which indeed no history can wisely ignore.

The spirit of mental science, subsumed under which were psychology and sociology, was voiced by Dr. G. Stanley Hall, an eager student of human life, who has achieved an encyclopedic learning; the creator of a school in the investigation of problems in mental science conceived and approached in a singularly generous spirit, who has made Clark University, of which he has been president since it was founded, preeminently an institution for psychological research; while, as teacher, editor and organizer, he has inspired an enthusiasm for the

inductive study of pedagogical problems which has made itself felt throughout the schools of the land. While Dr. Hall is one of few men who might have appropriately represented more than one of the great divisions of the congress, he chose on this occasion to discuss particularly the leading problems and methods of psychology, in an address spoken from the heart, abounding in fertile suggestions and no less characteristically teeming with allusions—an address which insisted on the continuity if not the identity of life and mind, and emphasized the urgent need of an objective study, at once comprehensive and thorough, of every concrete phase of experience in all its heterogeneous richness, as a basis for subsequent generalization under the guidance of the principle of evolution.

The division of utilitarian sciences, giving shelter to medicine, technology and economics, was generalled by President David Starr Jordan, of Leland Stanford University, eminent as a systematic zoologist, especially in ichthyology, who has placed his special knowledge at the service of the state in relation to questions of international import, and has admirably exemplified in his career what, as educator, writer and publicist, he has enunciated in no uncertain terms—the union of theory with practice in intelligent, effective work. President Jordan pointed out the unity of all the so-called utilitarian sciences in that they have their common source in disinterested investigation, at the same time claiming for pure research and practical application a relation of reciprocal dependence. Science is the guide of life and pure science must precede its applications, yet the utilities of science may not only determine the direction of its efforts but must ultimately control its results, measuring their exactness by the relentless standard of consequences.

The general interests of social regulation—in the sphere of politics, of jurisprudence and of those human groups with the economy of which social science is concerned—were entrusted to Mr. A. Lawrence Lowell, a distingushed member of a distinguished American family, professor of civil government in Harvard University, a scientific student of legislation, who has brought to the examination of political and legal institutions a ripe scholarship and an exceptionally critical mind. It is reported that in Professor Lowell's address the discussion took a somewhat practical turn, emphasizing especially the many-sided race problem, which was considered both historically and in relation to present-day conditions.

It almost goes without saying that the choice of a spokesman for social culture, through the great agencies of education and religion, fell upon the Honorable William T. Harris, U. S. Commissioner of Education, an alert survivor of the transcendentalist movement in America, celebrated for his learned familiarity with the history of civilization no less than for his indefatigable acuteness in the speculative interpretation of its principles after the manner of a philosophy

HAMMOND. PERRY. FRENCH. TUFTS. ORMOND. HÖFFDING. WARD. ARRHENIUS.
BOLTZMANN. CATTELL. OSTWALD. CREIGHTON. ERDMANN. LOEB.

Before the Addresses of Professors Ostwald and Erdmann on the Methodology of Science.

which has exerted a profound influence alike upon educational theory and upon religious thought, and withal a practical student and expert adviser in conspicuously active touch with the complex organization of instruction in our schools. Commissioner Harris doubtless traced the history of social culture from its first beginnings, as the unfolding temporal expression of an immanent purpose realizing itself through the instrumentality of human institutions, and having therefore from the start a unity of aim, at once natural and divine, namely, the perfection of spiritual citizenship in a rational society of personal selves.

Thus it was, in a general way, that these 'seven wise men' opened the gates of their respective fields of science. It is unfortunate that the aspiring listener was limited to the choice of a single one of this series. These men and their discourses have been chosen for specific characterization because they furnish a clue to the diversities as well as to the unities which pervaded the whole of the congress.

The divisional addresses over, the twenty-four departments were free to open fire. These were operated, eight at a time, at three intervals, scheduled for the late mornings and for the early and the late afternoons, respectively. It was thus possible for, say, the philosopher to do his duty by his own department at 11.15 while enjoying that of psychology at 2, with the freedom after 4 to choose between education, religion, sociology or some department farther afield, or yet again, to see something of the fair!

No account of the departments can be given which would be at all representative. Their titles have been already indicated under each of the divisions. It should be recorded that in general the departmental meetings were conducted by Americans, one in the chair and two with prepared addresses respectively on fundamental conceptions and methods, and on the history of progress during the last century. In some cases the fundamental character of the conceptions and methods discussed might be opened to question, and in others the ancient habit of beginning any history with Adam was not successfully inhibited, yet on the whole these departmental discourses did conform to the specifications prescribed, and the two addresses nicely supplemented each other. It remains only to illustrate the *personnel* a little more fully.

Taking philosophy as the first on the program, its chairman was Professor Borden P. Bowne, of Boston University, valued for his conservative temper, constructive scholarship, and the keen, clear and interesting analysis long familiar to a group of grateful students and readers. The historical paper was presented by Professor George Trumbull Ladd, celebrated for the comprehensiveness and thoroughness of his productive erudition over the whole field of mental and moral philosophy and as one who helped to lay the cornerstone of experimental psychology in America, whose name is honorably associated with

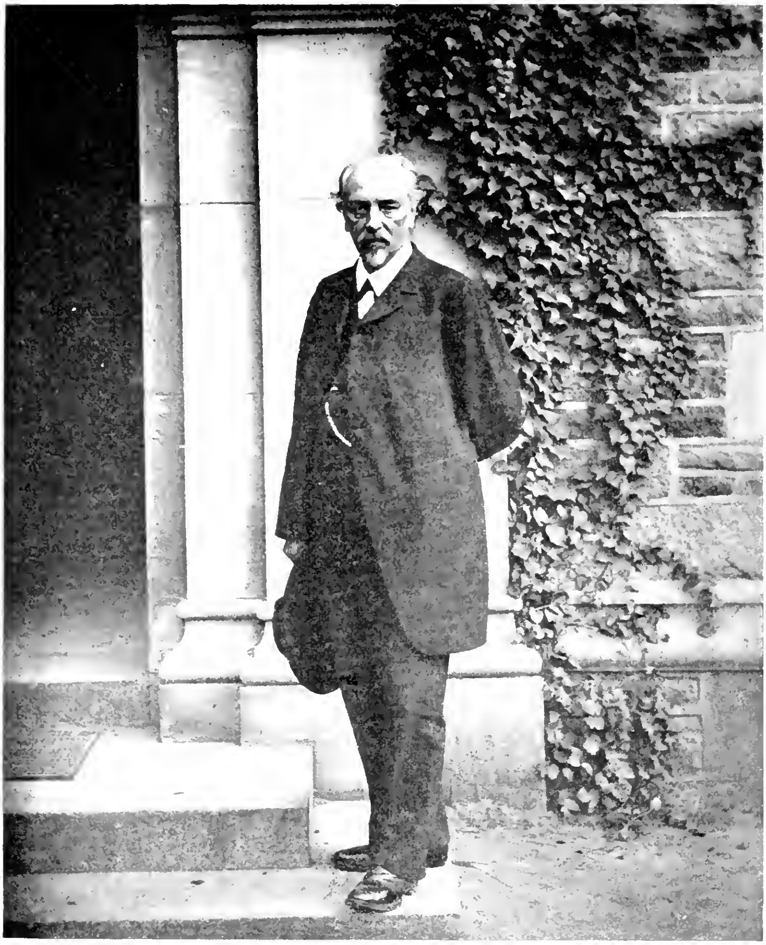
the department at Yale University, where he early founded a psychological laboratory which has taken high rank among like establishments throughout the world. The other paper for philosophy, read in the author's absence by Professor Charles M. Gayley, of the University of California, had been prepared by Professor George H. Howison, of that university, a man beloved and revered as an inspiring teacher of philosophy by a large and able body of students scattered over a continent, uniting intense moral fervor with a highly developed metaphysical imagination, and acknowledged as the most consistent defender of 'spiritual idealism' in academic circles.

Since it is impossible to mention by name all of the departmental speakers, let us glance at the list for the physical and mental sciences, sometimes called 'descriptive.' Nichols and Barus, Nef and Clarke, Pickering and Boss, Davis and Chamberlin, Loeb and Coulter, McGee and Boas, Baldwin and Cattell, Vincent and Giddings—of such names we need not be ashamed.

The important work of the 128 sections began on Wednesday and lasted through Saturday, the two sections in religious influence postponing their sessions till Sunday. Each sectional meeting occupied the greater part of a morning or an afternoon.

The offices of chairman and secretary for each of the sections were filled by Americans, chairmen being for the most part specialists of eminence, while the secretaries usually, although by no means invariably, represented a younger generation of scholars, conspicuous for promise.

To take the first group of sections, under philosophy, the chairmen were Professors Armstrong, of Wesleyan, for metaphysics; Thomas Hall, of Union Theological Seminary, for philosophy of religion; Duncan, of Yale, for logic; Creighton, of Cornell, for methodology of science; Palmer, of Harvard, for ethics, and Tufts, of Chicago, for esthetics. The secretaries, named in the same order, were Professor A. L. Lovejoy, of Washington University; Dr. W. P. Montague, of Columbia; Dr. W. H. Sheldon, of Columbia; Dr. Ralph Barton Perry, of Harvard; Professor F. C. Sharp, of Wisconsin; and Professor Max Meyer, of Missouri. The two principal speakers were supposed to treat one of the relations of their special science to neighboring sciences, in the interests of orientation and adjustment, the other of present problems demanding investigation in the immediate future. Many of the sections listened in addition to one or more ten-minute papers, which showed a tendency toward a general treatment of these topics harmonious with the principal addresses, although some were very special, in no sense intended to complete or supplement the main discussion. Thus one interesting paper made use of a lantern to illustrate the morphology and development of the kidney tubule. Impromptu discussion was opened in the section after the delivery of the formal communications. The principal addresses were made in



DR. BENNO ERDMANN, Professor of Philosophy at the University of Bonn, who gave one of the Addresses on the Methodology of Science.

some cases by two foreigners, in others by two Americans, but in most of them by a foreigner and an American scholar in turn.

Philosophy must again serve for illustration. The problems and relations of metaphysics were grappled with by two live thinkers, both authors of important recent books of a strictly metaphysical nature. The first was Professor A. E. Taylor, of McGill University, reputed for his firm and clear grasp of fundamental metaphysical and ethical problems and an exceptional acuteness in analysis. The second was Alexander T. Ormond, Princeton's influential teacher of philosophy, known as one of the few profoundly constructive metaphysical teachers among Americans, and a veritable paragon of synthesis in philosophy.

The philosophy of religion was shared by two eminent Germans,

DR. WILHELM OSTWALD, Professor of Chemistry at the University of Leipzig, who gave one of the Addresses on the Methodology of Science.

representing somewhat different standpoints: Dr. Otto Pfleiderer, the distinguished Berlin professor, a comparative historian and speculative thinker of the neo-Kantian persuasion, in the domain of religion, conceived as a logical development of ideas in history, and Professor Ernst Troeltsch, of Heidelberg, a philosopher to be sure, but eminent primarily as scientific student and critic of literary documents and historical sources in religion. Pfleiderer read in English, Troeltsch in German.

Two Americans spoke for logic. Professor Wm. A. Hammond, of Cornell, esteemed as a careful student of logic, metaphysics and psychology, especially in their historical aspects, and one of the few trained American scholars who has given serious attention to Greek philosophy, and Professor Frederick J. E. Woodbridge, of Columbia, who has made a marked impression as a scholarly teacher of philosophy, alike for originality and independence in the interpretation of philosophical systems and for the freshness which he has infused into metaphysical problems, while insisting on their intimate correlation with the problems of logic, in terms of which he has boldly defined them.

The session for the methodology of science was one of the most characteristic features of the whole congress. The subject itself is both new and fundamental, and perfectly typical of the class of problems for the consideration of which the congress was planned. It has to do with the determination and mutual adjustment of the concepts which underlie the special sciences and the methods peculiar to each, and is thus in the closest relation to logic and to the sciences themselves. A science of method must both conform to the laws of our minds and apply to the subject matter of experience which the sciences severally study. It was therefore essential that both speakers should be at the same time philosophers and men of science. And it was no less fitting than interesting that they should approach their subject by different roads. One is primarily a physical scientist, the other primarily a philosopher; both are preeminent. The first was Wilhelm Ostwald, of Leipzig, one of the most interesting personalities among living men of science. A brilliant investigator in the field of physical chemistry, where his name is linked with those of van't Hoff, Arrhenius and Nernst; a great teacher of chemistry and author of a monumental systematic treatise therein, conceived in a spirit original and unique; an ingenious expositor of the new doctrine of energetics in physical science; an enthusiastic student of philosophy, who has played up and down the whole gamut of the sciences; recently the founder of a new journal of natural philosophy, which is the acknowledged organ of a flourishing school:—such a man is Ostwald—a kind of 'modern Siegfried,' as an eminent colleague put it. The second speaker, also a German—

'He of the twice illustrious name,'

Benno Erdmann, of Bonn, a man profoundly learned in historical philosophy, who has advanced by important contributions, not unrelated, two such different sciences as experimental psychology and modern logic, in which he is an acknowledged master.

This session promised well from the start. The audience was representative in more ways than one. In addition to the professional philosophers, a number of remarkable men of science were present. In the front row, for instance, sat Svante Arrhenius, of Stockholm, physical chemist, famous for his mathematical and experimental contributions to the theory of solutions and speaker for cosmical physics, and Ludwig Boltzmann, of Vienna, mathematical physicist, distinguished especially for his work in the kinetic theory of gases, who represented applied mathematics in the program of the congress. Scattered through the audience were many eminent leading representatives of both the physical and mental sciences. Among Americans on the front were Loeb in biology and Cattell in psychology, both eminent specialists actively interested in scientific methods, both having applied exact methods with conspicuous success, albeit in very different ways, to the investigation of phenomena of life and mind. This is not the place to attempt a summary of the leading addresses, both delivered in German. Suffice it to point out that Ostwald presented a classification of the sciences professedly based on the empirical standpoint of energetics, and bearing but slight resemblance to the elaborate scheme which shaped the program of the congress. Erdmann attacked the subject from a frankly *à priori* point of view, arguing for the position which has recourse to a generating principle of logical necessity. Among those who took part in the open discussion were Boltzmann, Hoeffding, Ormond, Miss Calkins, etc., and the chief speakers again in reply.

In the section for ethics the speakers were Professor William R. Sorley, of Cambridge, able philosophical moralist, keen critic of the ethics of naturalism, who has made sound learning, astuteness and vigor of mind tell also in the study of the more vital questions of practice, and Professor Paul Hensel, of the University of Erlangen, philosophical scholar and critic, a gifted student of ethical theory and interpreter of ethical ideals in literature. The first address in the esthetics section was made by Dr. Henry Rutgers Marshall, of New York, a successful architect by profession, a philosopher by instinct and performance, distinguished as a philosophical student of psychology and a psychological student of esthetics, who has made interesting contributions to the analytical and genetic aspects of both sciences. The second speaker was Professor Max Dessoir, of the University of Berlin, erudite historian of German psychology in all its ramifications, himself a philosopher, psychologist and esthetician.

And so one might run through the long program, apart from a fortunate limitation of space and an unfortunate but inevitable igno-

rance. Without systematic attempt at characterization, let us swiftly glance at a few scattered sections. Thus E. H. Moore, of Chicago, presided over the section for algebra and analysis in which his colleague Heinrich Maschke spoke on the same platform with the illustrious Emile Picard, of the Sorbonne—a truly remarkable trio in the purest of pure sciences, the very problems of which are unknown variables even to the educated lay mind. Leave can not be taken of mathematics until attention is called to the immortal name of Poincaré, also of the Sorbonne, preeminent equally in pure mathematics and in their applications to physical research, especially to the problems of celestial mechanics, in which connection he has been called the 'Laplace of the present century.' Poincaré read his address before the section of applied mathematics.

Readers of the MONTHLY will be well familiar with the name of Karl Lamprecht, of Leipzig, great historian of Germanic culture and philosopher of history, who spoke without a note before the section of medieval history. Other sections of the same department were addressed by Mahaffy, of Dublin; Pais, of Naples; Cordier, of Paris; Bury, of Cambridge; Conrad, of Halle; while under the history of languages came MacDonell, of Oxford; Sonnenschein, of Birmingham; Jespersen, of Copenhagen; Paul Mayer and Lévi, of the Collège de France; and Sievers, of Leipzig, the highest authority in phonetics. Classical art was represented by Furtwängler, of Munich; modern painting by Muther, of Breslau, and the Japanese artist Okakura Kurozi, wearing native costume and attended by his lackeys. Sections devoted to the history of oriental religion heard Oldenberg, of Kiel; Goldziher, of Budapest; Budde, of Marburg; while the history of the Christian Church was discussed by that splendid historian Adolf Harnack, of Berlin, and the scarcely less distinguished Jean Reville, of the faculty of protestant theology of Paris, both of whom represented ecclesiastical history not as a thing apart, but as merely a distinguishable aspect within the continuous stream of civilization.

The physical sections are worthy of note for their threefold division into physics of matter, physics of ether, and physics of the electron. The last was discussed by Langevin, of the Collège de France, and the brilliant Rutherford, of McGill, whose experimental researches have resulted in the accepted theory of atomic distintegration as a cause of radioactivity. In one section Sir William Ramsay, in whose laboratory helium was first derived from radium, and the eminent French chemist, Henri Moissan, who, by the way, accomplished the manufacture of artificial diamonds in the laboratory, although his title to fame rests on a much broader foundation, discussed the science of inorganic chemistry. Physical chemistry was represented by the great van't Hoff, of Berlin, who developed the concept of osmotic pressure into a consistent theory of solutions and conceived the idea of

PROFESSOR K. MITSUKURI, OF THE UNIVERSITY OF TOKIO, WHO GAVE AN ADDRESS ON OCEANOGRAPHY.

the tetrahedral carbon atom in explanation of the behavior of substances chemically identical which nevertheless react differently to polarized light, thus creating the science of stereochemistry.

Besides Backlund, of Russia, the Dutch astronomer Kapteyn, of Groningen, celebrated for his measurements of stellar distances, discoursed on astronomy. Our own Campbell, of the Lick Observatory, delivered an admirable address on astrophysics, along with Turner, of Oxford. The section of paleontology, with Scott, of Princeton, in the chair, and John M. Clarke, New York

PROFESSOR JULIUS WIESNER, OF THE UNIVERSITY OF VIENNA, WHO GAVE AN ADDRESS ON PLANT PHYSIOLOGY.

state geologist, acting as secretary, was notable for its excellent address by Dr. A. Smith Woodward, F.R.S., the eminent systematic paleontologist of the British Museum of Natural History, and Professor Henry F. Osborn, of Columbia University and the American Museum of Natural History, together with the discussion which followed, of unusual interest, not only to paleontologists, but to geologists as well. Students of petrology and mineralogy heard Zirkel, of Leipzig, while those of physiography listened to Penck, of Vienna. The section of oceanography, manned by Rear-Admiral John R. Bartlett, U. S. N., in the chair, had the course of its deliberations directed by no less distinguished an explorer of the deep sea than Sir John Murray, K.C.B., of Edinburgh, aided by the eminent Professor K. Mitsukuri, of Tokio, a zoologist celebrated for his embryological researches and his knowledge of marine life in eastern waters.

The section of cosmical physics was another remarkable for the ideals of synthesis and the spirit of cooperation which pervaded it. In an address as bold as it was original Arrhenius proposed a theory of the possible connection between phenomena the most diverse and separated by exceedingly great distances, thus, *e. g.*, raising meteorology to the dignity of a cosmic science. Negatively charged electric corpuscles pass off from the sun and penetrate our atmosphere, producing its negative electricity, forming nuclei for the condensation of moisture, and so on, in intricate detail! Such students of meteorology and terrestrial magnetism as Drs. Rotch and Clayton, of the Blue Hill Observatory, and Dr. L. A. Bauer, of Washington, participated.

The biological sections were addressed by such eminent botanists from abroad as De Vries, of Amsterdam; Bower of Glasgow; Goebel, of Munich; Wiesner, of Vienna; and Drude, of Dresden; and by such representative zoologists as Giard, of Paris; Oskar Hertwig, of Berlin, recently made *rector magnificus* of the university; Delage, of Paris; Waldeyer, of Berlin; and Verworn, of Göttingen. Among the Americans who took part either as chairmen or speakers were Trelease and Bessey, Whitman, Brooks and Davenport, Meltzer, Howell and Theobald Smith. The section around which most interest centered was naturally that of phylogeny, presided over by T. H. Morgan, of Columbia, and addressed by De Vries and Whitman, one a botanist, the other a zoologist, both in the true sense biologists, who have directly investigated the problems of phylogeny and evolution by observation and experiment. De Vries, who has been in America since last spring, is professor in the University and director of the botanical gardens at Amsterdam, and eminent for a remarkable series of researches, experimental and theoretical, touching problems in physical chemistry and plant physiology, in the theory of heredity, and especially in the new experimental science of evolution. In the last named field De Vries has accomplished results which will make an epoch, at once demonstrating the fundamental thesis of Darwin, and supplementing the principles of Darwinism.

DR. HUGO MÜNSTERBERG, Professor of Psychology at Harvard University and Vice-President of the Congress, who proposed the Plan for the International Congress of Arts and Science.

For De Vries has been able to see with his own eyes the actual evolution of several new plant forms possessing the characters of true species, and has accumulated a vast amount of exact evidence, in support of the theory that new species arise suddenly from marked variations of the discontinuous sort, called 'mutations,' rather than by the gradual accumulation, through successive generations, of slight differences due to the ordinary 'fluctuating variation,' as Darwin had supposed.

This mutation theory of De Vries was discussed by its author before the section, while Whitman, after a general historical survey of his subject, discussed the interesting results obtained from a prolonged and controlled study of the evolution of color-pattern in the feathers of pigeons which he has bred for many years. Here the changes seem gradual, yet stable. As to the degree to which the two sets of results conflict, it would be premature to pronounce judgment.

Anthropologists were enabled to hear in their sectional meetings Manouvrier, of Paris, perhaps now the foremost name in physical anthropology; Seler, of Berlin, in American archeology; Haddon, of Cambridge, in ethnology.

The temptation must be resisted to report in detail the psychological sectional meetings. Denmark's ablest psychologist and England's, both eminent also in philosophy, discussed the relations and problems of general psychology with characteristic breadth and penetration. It was indeed a notable occasion when Hoeffding and Ward were introduced by Royce.

In another section Lloyd Morgan discussed the relations of the animal psychology which he may be said to have shaped for a band of younger workers who were in large part present to hear him, while Miss Mary W. Calkins, professor in Wellesley College, presented in excellent form a discriminating statement of the problems of genetic and comparative psychology in the large. As those addresses had been preceded by some well-chosen remarks by the chairman, Professor E. C. Sanford, who has directed important experimental work in comparative psychology, so they were followed by short papers of general methodological interest—one by the lamented Dr. C. L. Herrick, late editor of the *Journal of Comparative Neurology and Psychology*, read by Professor C. Judson Herrick, in which the dynamic or functional standpoint was emphasized; another by Dr. John B. Watson, of Chicago, urging the desirability of combining neurological studies, both experimental and histological, with systematic observations of animal behavior. Some matters of method, involving such questions as the criterion of consciousness, were broached in another short address, and there followed an interesting discussion which led to a pleasant lunch party.

The fascinating but baffling questions of abnormal psychology were discussed in another section by Dr. Pierre Janet, of the Salpêtrière, world-famed psychiatrist and psychologist, eminent as a

clinical investigator of abnormal conditions in the variegated and little understood field of the so-called psychic automatisms, obsessions, hysteria, 'multiple personality,' hypnotism, etc., whose penetrating analyses and fertile hypotheses have done much to bring unity and order into the chaos of phenomena presented. Dr. Morton Prince, an exceedingly clever Boston alienist, known also as a philosopher, offered an interesting array of facts from the field of the subconscious, which he subjected to an illuminating analysis. This section was particularly fortunate in having for its secretary an eminent alienist who has brought the methods and results of neurology and pathological anatomy, of physiology and psychology, together with clinical observation, to bear on a truly biological investigation of insanity—Dr. Adolf Meyer, of the New York State Pathological Institute.

One of the most interesting sessions was that for experimental psychology, in which a fundamental question of definition—far-reaching in its consequences for psychological research—was brought to a sharp issue in a fruitfully polemical address by Professor E. B. Titchener, Cornell's learned and thorough experimental psychologist, who has made a profound impression, not only upon a loyal group of students, but among psychologists everywhere, by reason of the distinctive point of view to which he has consistently adhered, no less than for the contagious enthusiasm of his devotion to the ideals of the experimental method. Titchener, after a masterly review of the present needs of experimental psychology, felt obliged to insist in sober earnest that psychology is in essence introspective, that introspection should be at the core of every psychological experiment, and that only those investigators who are concerned directly with conscious processes are properly psychologists at all, although it was conceded that much useful work—useful even for psychology *sensu stricto*—might be done by those who approach the subject more objectively, in the spirit of physiology or of biology, or, on the other side, from the standpoint of the theory of knowledge.

The interest attaching to the particular form which the discussion took before the experimental psychologists was enhanced by the fact that other psychologists had already, in their divisional and departmental addresses, favored the congress with their respective psychological creeds. For Hall, introspection was an almost anomalous by-product of evolution, for Cattell, only one of the methods of psychology. If Hall defined his science in terms of his general philosophy or *Weltanschauung*, and Titchener in terms of its most distinctive feature, Cattell may be said to have defined it inductively, in terms of the concrete interests of working psychologists as measured by their output. His was both a reasoned plea for a deliberate eclecticism in research, pending the adjustment of philosophical difficulties not easily banished, and a defense of a frank opportunism which has proved its usefulness. Ward's interests are apparently antipodal to Hall's. He

would agree with Titchener as to introspection, but in his address minimized the importance of sensations, and of just those simple, 'presented' aspects of experience which Titchener had emphasized as the most promising for study. Hall warned the psychologist against mathematics, while Cattell correlated psychology with the physical sciences and emphasized the need of exact methods, and Titchener found a large place for quantitative work. The psychology of Ward and Hoeffding seemed tenuous by contrast with that of all these others, while that of Janet and Prince occupied a place apart. Yet all were able discussions of psychology of some sort, and beneath the troubled surface was a common interest in 'minds,' many fathoms deep.

In the section for social structure there were three speakers, the noted Austrian field marshal, Gustav Ratzenhofer, of Vienna, the eminent social philosopher, Professor Toennies, of Kiel, and our own distinguished sociologist and paleobotanist, Lester F. Ward, of the U. S. National Museum.

One would despair of doing justice to the eminent representatives of the great and beneficent science of modern medicine, even if there were space for the attempt. Happily here, as perhaps generally in the case of the so-called utilitarian and other applied sciences, it will only be necessary to mention the names of a few of the leaders that addressed the congress to awaken appropriate associations in the reader's mind. For, most of the distinguished visitors who shared in the work of these sections enjoy, in addition to scientific eminence, a merited popular fame. Professor Ronald Ross, of the School of Tropical Medicine at Liverpool, whose name is a household word through his work on the rôle of the mosquito in the etiology of malarial fever, came for preventive medicine; Sir Lauder Brunton, of London, and Oscar Liebreich, of Berlin, for therapeutics and pharmacology; T. Clifford Allbutt, of Cambridge, for internal medicine; Sir Felix Semon, of London, for otology and laryngology; Theodor Escherich, of Vienna, for pediatrics; Shibasaburo Kitasato, of Tokio, bacteriologist and possibly Japan's most eminent man of science, for neurology. Many of our ablest American physicians and surgeons addressed the medical sections. In the only section which the writer was able to attend, that of psychiatry, after the excellent papers by Dr. Charles L. Dana, of New York, and Dr. Edward Cowles, of Boston, interesting remarks were made by several workers in neurology, psychiatry, and outlying fields, including such men as Janet, Hall, Ladd, Marshall, Prince, Meyer and Putnam.

The sections in technology, including the various branches of engineering, technical chemistry and agriculture, were conducted by prominent Americans, although the interest in this part of the program was scarcely commensurate with its importance. President Humphreys, of Stevens Institute, Professor Kennelly, of Harvard, Mr. John Hays Hammond, of New York, Professor Liberty H. Bailey, of

Cornell, and Hon. James Wilson, Secretary of Agriculture, were among the officers and speakers. The various branches of economics were discussed largely by Americans such as Clark in economic theory, Ripley in transportation, Seligman in public finance, and Hoffman in insurance, although Eugene von Philippovich came from Vienna.

In one of the political sections an address of exceptional interest was made by the Right Hon. James Bryce, M.P., eminent as a statesman, preeminent as a scholar in the field of political and legal history, gratefully honored by every educated American. The Hon. David Jayne Hill, our minister to Switzerland, spoke for diplomacy. Under jurisprudence, Professor La Fontaine, member of the Belgian Senate, spoke for international, and Signor Brunialti for constitutional, law. Professors Max Weber, Werner Sombart and T. Jastrow, and Dr. Emil Münsterberg, president of City Charities at Berlin, came from Germany alone for sections devoted to the social communities and groups. From abroad came Rein, of Jena, the eminent pedagogical philosopher, for educational theory; Michael E. Sadler, of Manchester, whose splendid work for public education in England has won the admiration of educators everywhere, for the section devoted to the school; M. Chabot, of Paris, for the university; and Guido Biagi, royal librarian at Florence, for the library. The section on the college listened to an address by that staunch and scholarly educator, President M. Carey Thomas, of Bryn Mawr College.

Among the speakers before the six sections concerned with practical religion were some who have exerted a wide popular influence, such as Rev. Hugh Black, of Edinburgh, Rabbi Hirsch, of Chicago, and Dr. Josiah Strong, of New York.

But the regular meetings were not enough. The Eighth International Geographic Congress, under the presidency of Commander Robert E. Peary, came to St. Louis to meet with the Congress of Arts and Science, and aroused considerable interest. Members of the congress having common technical interests were invited to special meetings of various sorts. Thus a Conference on Solar Research was held and an organization effected looking toward international cooperation among those interested in the investigation of solar problems. It is significant that almost all of the leading academies and other appropriate societies of the world which had been invited to cooperate, were ready with representatives from the membership of the congress.

Nor were the scientific meetings all. Men may be interesting though their theories be wrong. When they are known to have ideas and to have won distinction, they are especially interesting, even to those not technically familiar with their work. And while some scholars may seem neither to have inherited nor acquired the art of social enjoyment, the species is almost extinct, except in fiction and on the stage. There was entertainment enough, in varying degrees of informality, including the spontaneous formation of numerous

groups of manageable size for the investigation of 'The Pike.' No account of the congress would be complete which should fail to mention the series of formal entertainments arranged for its members. On Monday night the exposition celebrated the opening of the congress by special illuminations about the Grand Basin—a truly magnificent display. An attractive garden fête was given one afternoon at the French Pavilion by the Commissioner General from France. Another evening the German Imperial Commissioner General received at the German State House, with a hospitality that was handsome in its elegance and generosity. Other receptions were given by the Japanese Commissioner General and the Board of Lady Managers of the exposition. The Shaw banquet to the foreign delegates called forth numerous expressions of appreciation.

Perhaps in no event of the week was the informing spirit of the whole so impressively present to all as it was on the occasion of the closing banquet to the officers and speakers of the whole congress, tendered by the president of the exposition. In the great banquet hall of the Tyrolean Alps were assembled, for the second time, the whole *personnel* of the congress. The prevailing sentiment of scientific fellowship came out in all the speeches.

Commissioner Lewald made a ringing speech in German, Professor Darboux spoke in French, Signor Brunialti in Italian. Mr. Bryce, who spoke for British science with knowledge and with point, added that 'every meeting like this makes for international good will and every step like this is not only a step toward the advancement of knowledge: it is also a step toward the advancement of peace.' Notable too was the speech of Professor Nobushize Hozumi, of Tokio, one of the speakers in the section of comparative law and honorary vice-president for Japan. With winning felicity and consummate tact he expressed the pleasure which his countrymen had in cooperating with a distinguished Russian scholar in the congress, and added that this was the only place in which Japan could meet on equal terms that country with which it is at war in another part of the world.

The congress over, its members were soon scattered. Fortunately, many of the foreign guests were able to linger in our country for the purpose of traveling, visiting friends, or giving lectures. They were received by the President at the White House, also by Professor and Mrs. Newcomb in Washington; were entertained in Baltimore, Philadelphia, and elaborately in Boston and Cambridge by Professor Münsterberg and others; also at Yale and in New York, where the closing festivity was held under the auspices of the Association of Old German Students, and friendships old and new were cemented.

In what has preceded emphasis has been laid almost exclusively on the personal element. This it is which gave distinction to the congress and which made the most immediate impression. After the publication of the addresses, for which a special appropriation has

been made, it will be possible to study the ideas which were given expression in the meetings. Not until then will it be possible to estimate with safety the scientific outcome and value of the congress as a whole. It is certain, however, that the addresses were for the most part real contributions to science, and many of them of exceptional importance. It may strain the imagination of some to conceive of unification among subjects so diverse as logic and obstetrics, in spite of the Socratic simile. But it was the unity of ordered position in a complex system, and not without a sufficient number of intermediaries, that was sought, and in large measure realized. It would indeed have been a miracle if the sciences had simply been shaken together and a perfect kaleidoscopic picture had resulted. But such was not the case.

A unified classification had been prepared, as a means, not as an end, and elaborate as it was, it lent itself with remarkable fitness to the actual work of the congress. This does not mean that all the addresses conformed to the specifications in the same degree, or that those which heeded them most were always the most interesting. It is perhaps fair to say that if the dramatic unity of the whole was not mechanically perfect in its execution, it was ideally present throughout. Specialists were of course primarily interested in their own departments, but it was impossible not be conscious of the varied opulence of learning by which they were constantly surrounded and the one animating spirit of research with which the very atmosphere was surcharged. The leaders were mostly men whose previous interests and accomplishments were general and synthetic, as well as specialistic. Poincaré, Ostwald and Boltzmann might have been assigned to places in physical science; James Ward, to normative science; Arrhenius, to chemistry; Bryce, to history; while medicine would have been proud to open its doors to such savants as Waldeyer and Loeb.

A balanced evaluation of results must await the later work of better judges. Suffice it to remark in conclusion that a keen sentiment of mutual interest and respect was aroused and personal acquaintances were formed which should be an inspiration to all concerned. The congress will be a lasting monument to the idealism of the American spirit of enterprise. It gave a definite and a permanent expression to the scientific and social *Zeitgeist*. It must tend to quicken among scientific workers their sense of the multifarious variety of the human interests for which they labor, and to make for the desiderated extension of the methods of science to the whole domain of human life and effort, foreshadowing by the existing unity which it revealed a yet completer unity to be. And surely it had one great lesson, writ so large that all but the blind must have seen, and that is this: that science is the true bond of the nations, owing no allegiance save alone to truth, for which all the world may work in one spirit and by methods which are universal.

THE PRESENT PROBLEMS OF INORGANIC CHEMISTRY.*

BY SIR WILLIAM RAMSAY, K.C.B., F.R.S.

TO discuss the 'present problems of inorganic chemistry' is by no means an easy task. The expression might be taken to mean an account of what is being actually done at present by those engaged in inorganic research; or it might be taken to relate to what needs doing—to the direction in which research is required. To summarize what is being done in an intelligible manner in the time at my disposal would be an almost impossible task; hence I will choose the latter interpretation of the title of my address. Now, a considerable experience in attempting to unveil the secrets of nature has convinced me that a deliberate effort to discover some new law or fact seldom succeeds. The investigator generally begins unmethodically, by random and chance experiments; or perhaps he is guided by some indication which has struck his attention during some previous research; and he is often the plaything of circumstances in his choice. Experience leads him to choose problems which most readily admit of solution, or which appear likely to lead to the most interesting results. If I may be excused the egotism of referring to my own work, I may illustrate what I mean by relating the following curious coincidence: After Lord Rayleigh had announced his discovery that 'atmospheric nitrogen' was denser than 'chemical nitrogen,' I referred to Cavendish's celebrated paper on the combination of the nitrogen and the oxygen of the air by means of electric sparks. Fortified by what I read, and by the knowledge gained during the performance of lecture-experiments that red-hot magnesium is a good and fairly rapid absorbent of nitrogen, it was not long before a considerable quantity of nearly pure argon had been separated from atmospheric nitrogen. Now it happened that I possess two copies of Cavendish's works; and some months afterwards I consulted the other copy and found penciled on the margin the words 'look into this.' I remembered the circumstance which led to the annotation. About ten years before, one of my students had investigated the direct combination of nitrogen and hydrogen, and I had read Cavendish's memoir on that occasion. I mention this fact to show that for some reason which I forget, a line of work was not followed up, which would have been attended by most interesting results; one does not always follow the clue

* An address at the International Congress of Arts and Science, St. Louis, September, 1904.

which yields results of the greatest interest. I regard it therefore as an impossible task to indicate the lines on which research should be carried out. All that I can do is to call attention to certain problems awaiting solution; but their relative importance must necessarily be a matter of personal bias, and others might with perhaps greater right suggest wholly different problems.

The fundamental task of inorganic chemistry is still connected with the classification of elements and compounds. The investigation of the classification of carbon compounds forms the field of organic chemistry; while general or physical chemistry deals with the laws of reaction, and the influence of various forms of energy in furthering or hindering chemical change. And classification centers at present in the periodic arrangement of the elements, according to the order of their atomic weights. Whatever changes in our views may be concealed in the lap of the future, this great generalization, due to Newlands, Lothar Meyer and Mendelejev, will always retain a place, perhaps the prominent place, in chemical science.

Now it is certain that no attempt to reduce the irregular regularity of the atomic weights to a mathematical expression has succeeded; and it is, in my opinion, very unlikely that any such expression, of not insuperable complexity, and having a basis of physical meaning, will ever be found. I have already, in an address to the German Association at Cassel, given an outline of the grand problem which awaits solution. It can be shortly stated then: While the factors of kinetic and of gravitational energy, velocity and momentum, on the one hand, and force and distance, on the other, are simply related to each other, the capacity factors of other forms of energy—surface, in the case of surface-energy; volume, in the case of volume-energy; entropy for heat; electric capacity when electric charges are being conveyed by means of ions; atomic weight, when chemical energy is being gained or lost—all these are simply connected with the fundamental chemical capacity, atomic weight or mass. The periodic arrangement is an attempt to bring the two sets of capacity factors into a simple relation to each other; and while the attempt is in so far a success, inasmuch as it is evident that some law is indicated, the divergences are such as to show that finality has not been attained. The central problem in inorganic chemistry is to answer the question—why this incomplete concordance? Having stated the general question, it may conduce to clearness if some details are given.

1. The variation of molecular surface energy with temperature is such that the surface-energy, for equal numbers of molecules distributed over a surface, is equal for equal intervals of temperature below the temperature at which surface-energy is zero—that is, the critical point. This gives a means of determining the molecular weights of liquids, and we assume that the molecular weight of a compound is accurately the sum of the atomic weights of the constituent elements.

2. The volume-energy of gases is equal at equal temperature from that at which volume-energy is zero—*i. e.,* absolute zero. And it follows that those volumes of gases which possess equal volume-energy contain equal numbers of molecules—again, a close connection with atomic weights.

3. The specific heats of elements are approximately inversely proportional to their atomic weights; and of compounds to the quotient of their molecular weights divided by the number of atoms in the molecule. Specific heat and entropy are closely related; hence one of the factors of thermal energy is proportional (nearly) to the reciprocal of the atomic weights.

4. The ion carries in its migration through a solution one or more electrons. Now, the ion is an atom carrying one or more charges—one for each equivalent. Here we have the capacity for electric charge proportional to the equivalent.

5. The factors of chemical energy are atomic weight and chemical potential; and as the former is identical numerically, or after multiplication by a simple factor with equivalent, electric potential is proportional to chemical potential.

We see therefore that surface, volume, thermal, electrical, and, no doubt, other forms of energy have as capacity factors magnitudes, either identical with, or closely related to, units of chemical capacity; while kinetic and linear energy are not so related, except through the periodic arrangement of the elements.

It appears therefore to be a fundamental problem for the chemist to ascertain, first, accurate atomic weights, and, second, to investigate some anomalies which still present difficulties. In America, you have excellent workers in the former branch. Mallet, Morley, Richards and many others have devoted their time and skill to perhaps the best work of this kind which has been done; and F. W. Clarke has collated all results and afforded incalculable help to all who work at or are interested in the subject. Valuable criticisms, too, have been made by Hinrichs; but it must be confessed that in spite of these, which are perhaps the best determinations which have been made, the problem becomes more, and not less formidable.

There are lines of work, however, which suggest themselves as possibly likely to throw light on the question. First, there is a striking anomaly in the atomic weight of nitrogen, determined by analysis and determined by density. Stas obtained the number 14.04 ($O = 16$), and Richards has recently confirmed his results; while Rayleigh and Leduc consistently obtained densities which, even when corrected so as to equalize the numbers of molecules in equal volumes, give the lower figure 14.002. The difference is 1 in 350; far beyond any possible experimental error. Recently, an attempt to combine the two methods has led to a mean number; but that result can hardly be taken as final. What is the reason of the discrepancy? Its discovery will surely ad-

vance knowledge materially. I would suggest the preparation of pure compounds of nitrogen, such as salts of hydrazine, methylanine, etc., and their careful analysis; and also the accurate determination of the density and analysis of such gaseous compounds of nitrogen as nitric oxide and peroxide. I have just heard from my former student, W. R. W. Gray, that he has recovered Stas's number by combining 2NO with O_2; while the density of NO leads to the lower value for the atomic weight of nitrogen.

The question of the atomic weight of tellurium appears to be settled, at least so far as its position with regard to the generally accepted atomic weight of iodine is concerned; recent determinations give the figures 127.5 (Gutbier), 127.6 (Pellini), and 127.9 (Köthner). But is that of iodine as accurately known? It would appear advisable to revise the determination of Stas, preparing the iodine preferably from an organic compound, such as iodoform, which can be produced in a high state of purity. The heteromorphism of selenates and tellurates, too, has recently been demonstrated; and it may be questioned whether these elements should both belong to the same group.

The rare earths still remain a puzzle. Their number is increasing yearly, and their claim to individuality admits of less and less dispute. What is to be done with them? Are they to be grouped by themselves as Brauner and Steele propose? If so, how is their connection with the other elements to be explained? Recent experiments in my laboratory have convinced me that in the case of thorium, at least, ordinary tests of purity such as fine crystals, constant subliming point, etc., do not always indicate homogeneity; or else that we are sadly in want of some analytical method of sufficient accuracy. The change of thorium into thorium X is perhaps hardly an explanation of the divergencies; yet it must be considered; but of this, more anon.

To turn next to another problem closely related to the orderly arrangement of the elements—that of valency—but little progress can be chronicled. The suggestions which have been made are speculative, rather than based on experiment. The existence of many peroxidized substances, such as percarbonates, perborates, persulphates and of crystalline compounds of salts with hydrogen peroxide, makes it difficult to draw any indisputable conclusions as regards valency from a consideration of oxygen compounds. Moissan's brilliant work on fluorides, however, has shown that SF_6 is capable of stable existence, and this forms a strong argument in support of the hexad character of sulphur. The tetravalency of oxygen, under befitting conditions, too, is being acknowledged, and this may be reconciled with the existence of water of crystallization, as well as of the per-salts already mentioned. The adherence of ammonia to many chlorides, nitrates, etc., points to the connecting link being ascribable to the pentavalency of nitrogen; and it might be worth while investigating similar compounds

with phosphoretted and arsenicoretted hydrogen, especially at low temperatures.

The progress of chemical discovery, indeed, is closely connected with the invention of new methods of research, or the submitting of matter to new conditions. While Moissan led the way by elaborating the electric furnace, and thus obtained a potent agent in temperatures formerly unattainable, Spring has tried the effect of enormous pressure, and has recently found chemical action between cuprous oxide and sulphur at ordinary temperature, provided the pressure be raised to 8,000 atmospheres. Increase of pressure appears to lower the temperature of reaction. It has been known for long that explosions will not propagate in rarefied gases, and that they become more violent when the reacting gases are compressed: but we are met with difficulties, such as the non-combination of hydrogen and nitrogen, even at high temperature and great pressure; yet it is possible to measure the electromotive force (0.59 volt) in a couple consisting of gaseous nitrogen and gaseous hydrogen, the electrolyte being a solution of ammonium nitrate saturated with ammonia. Chemical action between dissolved hydrogen and nitrogen undoubtedly occurs; but it is not continuous. Again we may ask, Why? The heat evolution should be great; the gain of entropy should also be high were direct combination to occur. Why does it not occur to any measurable extent? Is it because for the initial stages of any chemical reaction, the reacting molecules must be already dissociated, and those of nitrogen are not? Is that in any way connected with the abnormally low density of gaseous nitrogen? Or is it that, in order that combination shall occur, the atoms must fit each other; and that in order that nitrogen and hydrogen atoms may fit, they must be greatly distorted? But these are speculative questions, and it is not obvious how experiments can be devised to answer them.

Many compounds are stable at low temperatures which dissociate when temperature is raised. Experiments are being made, now that liquid air is to be purchased or cheaply made, on the combinations of substances which are indifferent to each other at ordinary temperatures. Yet the research must be a restricted one, for most substances are solid at — 185°, and refuse to act on each other. It is probable, however, that at low temperatures compounds could be formed in which one of the elements would possess a greater valency than that usually ascribed to it: and also that double compounds of greater complexity would prove stable. Valency, indeed, appears to be in many cases a function of temperature; exothermic compounds, as is well known, are less stable, the higher the temperature. The sudden cooling of compounds produced at a high temperature may possibly result in forms being preserved which are unstable at ordinary temperatures. Experiments have been made in the hope of obtaining compounds of argon and helium by exposing various elements to the influence of sparks from

a powerful induction coil, keeping the walls of the containing-vessel at the temperature of liquid air, in the hope that any endothermic compound which might be formed would be rapidly cooled, and would survive the interval of temperature at which decomposition would take place naturally. But these experiments have so far yielded only negative results. There is some indication, however, that such compounds are stable at 1,500°. It might be hoped that a study of the behavior of the non-valent elements would have led to some conception of the nature of valency; but so far, no results bearing on the question have transpired. The condition of helium in the minerals from which it is obtainable by heat is not explained; and experiments in this direction have not furnished any positive information. It is always doubtful whether it is advisable to publish the results of negative experiments; for it is always possible that some more skilled or more fortunate investigator may succeed, where one has failed. But it may be chronicled that attempts to cause combination between the inactive gases and lithium, potassium, rubidium, and cæsium have yielded no positive results; nor do they appear to react with fluorine. Yet conditions of experiment play a leading part in causing combination, as has been well shown by Moissan with the hydrides of the alkali-metals, and by Guntz, with those of the metals of the alkaline earths. The proof that sodium hydride possesses the formula NaH, instead of the formerly accepted one, removes one difficulty in the problem of valency; and SrH_2 falls into its natural position among hydrides.

A fertile field of inorganic research lies in the investigation of structure. While the structure of organic compounds has been elucidated almost completely, that of inorganic compounds is practically undeveloped. Yet efforts have been made in this direction which appear to point a way. The nature of the silicates has been the subject of research for many years by F. W. Clarke; and the way has been opened. Much may be done by treating silicates with appropriate solvents, acid or alkaline, which differentiate between uncombined and combined silica, and which in some cases, by replacement of one metal by another, gives a clue to constitution. The complexity of the molecules of inorganic compounds, which are usually solid, forms another bar to investigation. It is clear that sulphuric acid, to choose a common instance, possesses a very complicated molecule; and the fused nitrates of sodium and potassium are not correctly represented by the simple formulæ $NaNO_3$ and KNO_3. Any theory of the structure of their derivatives must take such facts into consideration; but we appear to be getting nearer the elucidation of the molecular weights of solids. Again, the complexity of solutions of the most common salts is maintained by many investigators; for example, a solution of cobalt chloride, while it undoubtedly contains among other constituents simple molecules of $CoCl_2$, also consists of ions of a complex character, such as

$(CoCl_4)''$. And what holds for cobalt chloride also undoubtedly holds for many similar compounds.

In determining the constitution of the compounds of carbon, stereochemistry has played a great part. The ordinary structural formulæ are now universally acknowledged to be only pictorial, if, indeed, that word is legitimate; perhaps it would be better to say that they are distorted attempts at pictures, the drawing of which is entirely free from all rules of perspective. But these formulæ may in almost every case be made nearly true pictures of the configuration of the molecules. The benzine formula, to choose an instance which is by no means the simplest, has been shown by Collie to be imitated by a model which represents in an unstrained manner the behavior of that body on treatment with reagents. But in the domain of inorganic chemistry, little progress has been made. Some ingenious ideas of the geologist Sollas on this problem have hardly received the attention which they deserve; perhaps they may have been regarded as too speculative. On the other hand, Le Bel's and Pope's proof of the stereo-isomerism of certain compounds of nitrogen; Pope's demonstration of the tetrahedral structure of the alkyl derivatives of tin; and Smiles's syntheses of stereo-isomeric sulphur compounds give us the hope that further investigation will lead to the classification of many other elements from this point of view. Indeed, the field is almost virgin soil; but it is well worth while cultivating. There is no doubt that the investigation of other organo-metallic compounds will result in the discovery of stereo-isomerides; yet the methods of investigation capable of separating such constituents have in most cases still to be discovered.

The number of chemical isomerides among inorganic compounds is a restricted one. Werner has done much to elucidate this subject in the case of complex ammonia derivatives of metals and their salts; but there appears to be little doubt that if looked for, the same or similar phenomena would be discoverable in compounds with much simpler formulæ. The two forms of So_3, sulphuric anhydride, are an instance in point. No doubt formation under different conditions of temperature and pressure might result in the greater stability of some forms which under our ordinary conditions are changeable and unstable. The fact that under higher pressures than are generally at our disposal different forms of ice have been proved to exist, and the application of the phase-rule to such cases, will greatly enlarge our knowledge of molecular isomerism.

The phenomena of catalysis have been extensively studied of recent years, and have obviously an important bearing on such problems. A catalytic agent is one which accelerates or retards the velocity of reaction. Without inquiring into the mechanism of catalysis, its existence may be made to influence the rate of chemical change, and to render stable bodies which under ordinary conditions are unstable. For if it is possible to accelerate a chemical change in such a way that the

usually slow and possibly unrecognizable rate of isomeric change may be made apparent and measurable, a substance the existence of which could not be recognized under ordinary circumstances, owing to its infinitesimal amount, may be induced to exist in weighable quantity, if the velocity of its formation from an isomeride can be greatly accelerated by the presence of an appropriate catalytic agent. I am not aware that attempts have been made in this direction. The discovery of catalytic agents is, as a rule, the result of accident. I do not think that any guide exists which would enable us to predict that any particular substance would cause an acceleration or a retardation of any particular reaction. But catalytic agents are generally those which themselves, by their power of combining with or parting with oxygen, or some other element, cause the transfer of that element to other compounds to take place with increased or diminished velocity. It is possible, therefore, to cause ordinary reactions to take place in presence of a third body, choosing the third body with a view to its catalytic action, and to examine carefully the products of the main reaction as regards their nature and their quantity. Attempts have been made in this direction with marked success; the rate of change of hydrogen dioxide, for example, has been fairly well studied. But what has been done for that compound may be extended indefinitely to others, and doubtless with analogous results. Indications of the existence of as yet undiscovered compounds may be derived from a study of physical, and particularly of electrical, changes. There appears to be sufficient evidence of an oxide of hydrogen containing more oxygen than hydrogen dioxide, from a study of the electromotive force of a cell containing hydrogen dioxide; yet the higher oxide still awaits discovery.

The interpretation of chemical change in the light of the ionic theory may now be taken as an integral part of inorganic chemistry. The ordinary reactions of qualitative and quantitative analysis are now almost universally ascribed to the ions, not to the molecules. And the study of the properties of most ions falls into the province of the inorganic chemist. To take a familiar example: The precipitation of hydroxides by means of ammonia-solution has long led to the hypothesis that the solution contained ammonium hydroxide; and, indeed, the teaching of the text-books and the labels on the bottles supported this view. But we know now that a solution of ammonia in water is a complex mixture of liquid ammonia and liquid water; of ammonium hydroxide, NH_4OH; and of ions of ammonium $(NH_4)'$, and hydroxyl $(OH)'$. Its reactions, therefore, are those of such a complex mixture. If brought into contact with a solution of some substance which will withdraw the hydroxyl ions, converting them into water, or into some non-ionized substance, they are replaced at the expense of the molecules of non-ionized ammonium hydroxide; and these, when diminished in amount, draw on the store of molecules of ammonia and water, which combine, so as to maintain equilibrium. Now the investigation of such

changes must belong to the domain of inorganic chemistry. It is true that the methods of investigation are borrowed from the physical chemist; but the products lie in the province of the inorganic chemist. Indeed, the different departments of chemistry are so interlaced that it is impossible to pursue investigations in any one branch without borrowing methods from the others; and the inorganic chemist must be familiar with all chemistry, if he is to make notable progress in his own branch of the subject. And if the substances and processes investigated by the inorganic chemist are destined to become commercially important, it is impossible to place the manufacture on a sound commercial basis without ample knowledge of physical methods, and their application to the most economical methods of accelerating certain reactions and retarding others, so as to obtain the largest yield of the required product at the smallest cost of time, labor and money.

I have endeavored to sketch some of the aspects of inorganic chemistry with a view to suggesting problems for solution, or at least the directions in which such problems are to be sought. But the developments of recent years have been so astonishing and so unexpected, that I should fail in my duty were I not to allude to the phenomena of radioactivity, and their bearing on the subject of my address. It is difficult to gauge the relative importance of investigations in this field; but I may be pardoned if I give a short account of what has already been done, and point out lines of investigation which appear to me likely to yield useful results.

The wonderful discovery of radium by Madame Curie, the preparation of practically pure compounds of it, and the determination of its atomic weight are familiar to all of you. Her discovery of polonium, and Debierne's of actinium have also attracted much attention. The recognition of the radioactivity of uranium by Becquerel, which gave the first impulse to these discoveries, and of that of thorium by Schmidt, is also well known.

These substances, however, presented at first more interest for the physicist than the chemist, on account of the extraordinary power which they all possess of emitting 'rays.' At first, these rays were supposed to constitute ethereal vibrations; but all the phenomena were not explicable on that supposition. Schmidt first, and Rutherford and Soddy later, found that certain so-called 'rays' really consist of gases; and that while thorium emits one kind, radium emits another; and no doubt Debierne's actinium emits a third. The name 'emanations' was applied by Rutherford to such radioactive bodies; he and Soddy found that those of radium and thorium could be condensed and frozen by exposure to the temperature of liquid air, and that they were not destroyed or altered in any way by treatment with agents which are able to separate all known gases from those of the argon group, namely, red-hot magnesium-lime, and it was later found that sparking with oxygen in presence of caustic potash did not affect the

gaseous emanation from radium. The conclusion therefore followed that in all probability these bodies are gases of the argon group, the atomic weight of which, and consequently the density, is very high; indeed, several observers, by means of experiments on the rate of diffusion of the gas from radium, believe it to have a density of approximately 100, referred to the hydrogen standard. This conclusion has been confirmed by the mapping of the spectrum of the radium emanation, which is similar in general character to the spectra of the inactive gases, consisting of a number of well-defined, clearly cut brilliant lines, standing out from a black background. The volume of the gas produced spontaneously from a given weight of radium bromide in a given time has been measured; and it was incidentally shown that this gas obeys Boyle's law of pressures. The amount of gas thus collected and measured, however, was very minute; the total quantity was about the forty-thousandth of a cubic centimeter.

Having noticed that those minerals which consist of compounds of uranium and thorium contain helium, Rutherford and Soddy made the suggestion that it might not be impossible that helium is the product of the spontaneous change of the emanation; and Soddy and I were able to show that this is actually the case. For, first, when a quantity of a radium salt which has been prepared for some time is dissolved in water, the occluded helium is expelled, and can be recognized by means of its spectrum; further, the fresh emanation shows no helium spectrum, but after a few days the spectrum of helium begins to appear, proving that a spontaneous change is in progress; and last, as the emanation disappears its volume decreases to zero; and on heating the capillary glass tube which contained it, helium is driven out from the glass walls, into which its molecules had been imbedded in volume equal to three and a half times that of the emanation. The α-rays, as foreshadowed by Rutherford and Soddy, consist of helium particles.

All these facts substantiate the theory, devised by Rutherford and Soddy, that the radium atom is capable of disintegration, one of the products being a gas, which itself undergoes further disintegration, forming helium as one of its products. Up till now, the sheet anchor of the chemists has been the atom. But the atom itself appears to be complex, and to be capable of decomposition. It is true that only in the case of a very few elements, and these of high atomic weight, has this been proved. But even radium, the element which has by far the most rapid rate of disintegration, has a comparatively long life; the period of half-change of any given mass of radium is approximately 1,100 years. The rate of change of the other elements is incomparably slower. This change, too, at least in the case of radium, and its emanation, and presumably also in the case of other elements, is attended with an enormous loss of energy. It is easy to calculate from heat measurements (and independent and concordant measurements have been made) that one pound of emanation is capable of parting with

as much energy as several hundred tons of nitroglycerine. The order of the quantity of energy evolved during the disintegration of the atom is as astonishing as the nature of the change. But the nature of the change is parallel to what would take place if an extremely complicated hydrocarbon were to disintegrate; its disruption into simpler paraffins and olefines would also be attended with loss of energy. We may therefore take it, I think, that the disintegration hypothesis of Rutherford and Soddy is the only one which will meet the case.

If radium is continually disappearing, and would totally disappear in a very few thousand years, it follows that it must be reproduced from other substances, at an equal rate. The most evident conjecture, that it is formed from uranium, has not been substantiated. Soddy has shown that salts of uranium, freed from radium, and left for a year, do not contain one ten-thousandth part of the radium that one would expect to be formed in the time. It is evident therefore that radium must owe its existence to the presence of some other substances, but what they are is still unascertained.

During the investigation of Rutherford and Soddy of the thorium emanation, a most interesting fact was observed, namely, that precipitation of the thorium as hydroxide by ammonia left unprecipitated a substance, which they termed thorium-X, and which was itself highly radio-active. Its radio-active life, however, was a short one; and as it decayed, it was reproduced from its parent thorium at an equal rate. Here is a case analogous to what was sought for with radium and uranium; but evidently uranium is not the only parent of radium; the operation is not one of parthenogenesis. Similar facts have been elicited for uranium by Crookes.

The α-rays, caused by the disintegration of radium and of its emanation, are accompanied by rays of quite a different character; they are the β-rays, identical with electrons, the mass of which has been measured by J. J. Thomson and others. These particles are projected with enormous velocity, and are capable of penetrating glass and metal screens. The power of penetration appears to be proportional to the amount of matter in the screen, estimated by its density. These electrons are not matter; but, as I shall relate, they are capable of causing profound changes in matter.

For the past year, a solution of radium bromide has been kept in three glass bulbs each connected to a Topler pump by means of capillary tubing. To ensure these bulbs against accident, each was surrounded by a small beaker; it happened that one of these beakers consisted mainly of potash glass; the other two were of soda glass. The potash-glass beaker became brown, while the two soda-glass beakers became purple. I think there is every probability that the colors are due to liberation of the metals potassium and sodium in the glass. They are contained in that very viscous liquid, glass, in the colorless ionic state; but these ions are discharged by the β-rays, or negative

electrons, and each metal imparts its own peculiar color to the glass, as has been shown by Maxwell Garnett. This phenomenon, however interesting, is not the one to which I desire to draw special attention. It must be remembered that the beakers have been exposed only to β-rays; α-rays have never been in contact with them; they have never been bombarded by what is usually called matter, except by the molecules of the surrounding air. Now these colored beakers are radioactive, and *the radioactive film dissolves in water.* After careful washing, the glass was no longer radioactive. The solution contains an emanation, for on bubbling air through it, and cooling the issuing air with liquid air, part of the radioactive matter was retained in the cooled tube. This substance can be carried into an electroscope by a current of air, after the liquid air has been withdrawn, and as long as the air-current passes, the electroscope is discharged; the period of decay of this emanation, however, is very rapid, and on ceasing the current of air, the leaves of the electroscope cease to be discharged. In having such a short period of existence, this emanation resembles the one from actinium.

Owing to the recess, only a commencement has been made with the investigation of the residue left on evaporation of the aqueous solution. On evaporation, the residue is strongly active. Some mercurous nitrate was then added to the dissolved residue, and it was treated with hydrochloric acid in excess, to precipitate mercurous chloride. The greater part of the active matter was thrown down with the mercurous chloride, hence it appears to form an insoluble chloride. The mercurous chloride retained its activity unchanged in amount for ten days. The filtrate from the mercurous chloride, on evaporation, turned out to be active; and on precipitating mercuric sulphide in it, the sulphide precipitate was also active; but its activity decayed in one day. The filtrate from the mercuric sulphide gave inactive precipitates with ferric salts and ammonia, with zinc salts and ammonium sulphide, with calcium salts and ammonium carbonate; and on final evaporation, the residue was not radioactive. Hence the active matter forms an insoluble chloride and sulphide. The precipitated mercurous chloride and mercuric sulphide were dissolved in *aqua regia,* and the solution was evaporated. The residue was dissolved in water, and left the dish inactive. But the solution gave an insoluble sulphate, when barium chloride and sulphuric acid were added to it, hence the radioactive element forms an insoluble sulphate, as well as an insoluble chloride and sulphide.

This is a sample of the experiments which have been made. It may be remarked that the above results were obtained from a mixture of the potash and soda glass; somewhat different results were obtained from the potash glass alone. These changes appear to be due to the conversion of one or more of the constituents of the glass into other

bodies. Needless to say, neither of the samples of glass contained lead.

I have mentioned these experiments in detail, because I think they suggest wholly new lines of investigation. It would appear that if energy can be poured into a definite chemical matter, such as glass, it undergoes some change, and gives rise to bodies capable of being tested for; I imagine that radio-active forms of matter are produced, either identical with or allied to, those at present known. And just as radium and other radio-active elements suffer degradation spontaneously, evolving energy, so I venture to think that if energy be concentrated in the molecules of ordinary forms of matter, a sort of polymerization is the result, and radio-active elements, probably elements with high atomic weight, and themselves unstable, are formed. Of course further research may greatly modify these views; but some guide is necessary, and Mr. Ternent Cook, who has helped me in these experiments, and I suggest this hypothesis (in the words of Dr. Johnstone Stoney, a hypothesis is 'a supposition which we hope may be useful') to serve as a guide for future endeavor.

In the light of such facts, speculation on the periodic arrangement of the elements is surely premature. It is open to any one to make suggestions; they are self-evident. Most of you will agree with the saying 'it is easy to prophesy after the event.' I prefer to wait until prophecy becomes easy.

I must ask your indulgence for having merely selected a few out of the many possible views as regards the Problems of Inorganic Chemistry. I can only plead in excuse that my task is not an easy one; and I venture to express the hope that some light has been thrown on the shady paths which penetrate that dark region which we term the future.

THE LIGHT OF THE STARS.*

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IF an intelligent observer should see the stars for the first time, two of their properties would impress him as subjects for careful study; first, their relative positions, and secondly, their relative brightness. From the first of these has arisen the astronomy of position, or astrometry. This is sometimes called the old astronomy, since until within the last twenty years the astronomers of the world, with few exceptions, devoted their attention almost entirely to it. To the measure of the light should be added the study of the color of the stars (still in its infancy), and the study of their composition by means of the spectroscope. In this way a young giant has been reared, which has almost dwarfed its older brothers. The science of astrophysics, or the new astronomy, has thus been developed, which during the last few years has rejuvenated the science and given to it, by its brilliant discoveries, a public interest which could not otherwise have been awakened. The application to stellar astronomy, of the daguerreotype in 1850, of the photograph in 1857, and of the dry plate in 1882, has opened new fields in almost every department of this science. In some, as in stellar spectroscopy, it has almost completely replaced visual observations.

One department of the new astronomy, the relative brightness of the stars, is as old as, or older than, the old astronomy. An astronomer even now might do useful work in this department without any instruments whatever. Hipparchus is known to have made a catalogue of the stars about 150 B. C. Ptolemy, in 138 A. D., issued that great work, the Almagest, which for fourteen hundred years constituted the principal and almost the sole authority in astronomy. It contained a catalogue of 1,028 stars, perhaps based on that of Hipparchus. Ptolemy used a scale of stellar magnitudes which has continued in use to the present day. He called the brightest stars in the sky, the first magnitude, the faintest visible to the naked eye, the sixth. More strictly, he used the first six letters of the Greek alphabet for this purpose. But he went a step further, and subdivided these classes. If a star seemed bright for its class, he added the letter μ (mu), standing for μειζων (meizon), large or bright; if the star was faint, he added ε (epsilon), standing for ελασσων (elasson), small or faint. These

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estimates were presumably carefully made, and if we had them now, they would be of the greatest value in determining the secular changes, if any, in the light of the stars. The earliest copy we have of the Almagest is No. 2,389 of the collection in the Bibliothèque Nationale of Paris. It is a beautiful manuscript written in the uncial characters of the ninth century. A few years ago it could be seen by any one in one of the show cases of the library. There are many later manuscripts and printed editions which have been compared by various students. The errors in these various copies are so numerous that there is an uncertainty in the position, magnitude, or identification of about two thirds of the stars. A most important revision was made by the Persian astronomer, Abd-al-rahman al-sufi, who reobserved Ptolemy's stars, A. D. 964, and noted the cases in which he found a difference. The careful study and translation of this work from Arabic into French by Schjellerup has rendered it readily accessible to modern readers.

No important addition to our knowledge of the light of the stars was made until the time of Sir William Herschel, the greatest of modern observers. He found that when two stars were nearly equal, the difference could be estimated very accurately. He designated these intervals by points of punctuation, a period denoting equality, a comma a very small interval, and a dash a larger interval. In 1796 to 1799 he published, in the *Philosophical Transactions,* four catalogues, covering two thirds of the portion of the sky visible in England. Nearly a century later, it was my great good fortune, when visiting his grandson, to discover in the family library the two catalogues required to complete this work, and which had not been known to exist. These two catalogues are still unpublished. Meanwhile, little or no use had been made of the four published catalogues which, while comparing one star with another, furnished no means of reducing all to one system of magnitudes. The Harvard measures permitted me to do this for all six catalogues, and thus enabled me to publish magnitudes for 2,785 stars observed a century ago, with an accuracy nearly comparable with the best work of the present time. For nearly half a century no great advance was made, and no astronomer was wise enough to see how valuable a work he could do by merely repeating the observations of Herschel. Had this work been extended to the southern stars, and repeated every ten years, our knowledge of the constancy of the light of the stars would have been greatly increased. In 1844, Argelander proposed, in studying variable stars, to estimate small intervals modifying the method of Herschel by using numbers instead of points of punctuation, and thus developed the method known by his name. This is now the best method of determining the light of the stars, when only the naked eye or a telescope is available, and much valuable work might be done by applying it to the fainter stars, and especially to clusters.

Meanwhile photometric measures of the stars, according to various methods, had been undertaken. In 1856, Pogson showed that the scale of magnitudes of Ptolemy, which is still in use, could be nearly represented by assuming the unit to be the constant ratio, 2.512, whose logarithm is 0.4. This has been generally adopted as the basis of the standard photometric scale. The photometer devised by Zöllner has been more widely used than any other. In this instrument an artificial star is reduced any desired amount, by polarized light, until it appears to equal the real star, both being seen side by side in the telescope. Work with this instrument has attained its greatest perfection at the Potsdam Observatory, where measures of the light of the northern stars, whose magnitude is 7.5 and brighter, have been in progress since 1886. The resulting magnitudes have been published for 12,046 stars, included in declination between —2° and —60°. The accidental errors are extremely small, but as the results of different catalogues differ systematically from one another, we can not be sure which is right and what is the real accuracy attained in each case. In 1885 the Uranometria Oxoniensis was published. It gives the magnitudes of 2,784 northern stars north of declination — 10°. This work is a remarkable one, especially as its author, Professor Pritchard, began his astronomical career at the age of sixty-three. The method he employed was reducing the light of the stars by means of a wedge of shade glass until they became invisible, and then determining the brightness from the position of the wedge. A careful and laborious investigation, extending over many years has been carried on by Mr. H. M. Parkhurst, using a modification of this method.

For several years before the Oxford and Potsdam measures described above were undertaken, photometric observations were in progress at Harvard. In 1877 a large number of comparisons of adjacent stars were made with a polarizing photometer. Two images of each star were formed with a double image prism, and the relative brightness was varied by turning a Nicol prism until the ordinary image of one star appeared equal to the extraordinary image of the other. Several important sources of error were detected, which once known were easily eliminated. A bright star will greatly affect the apparent brightness of an adjacent faint one, the error often exceeding a magnitude. Systematic errors amounting to several tenths of a magnitude depend upon the relative positions of the images compared. They are perhaps due to the varying sensitiveness of the different parts of the retina. This photometer has many important advantages. However bad the images may be, they are always exactly alike, and may, therefore, be compared with accuracy. Both stars are affected equally by passing clouds, so that this photometer may be used whenever the stars are visible and at times when other photometric work is impossible. The diminution in light also follows a simple geometrical law, and is readily computed with great accuracy. There is no unknown constant to be

determined, as in the Pritchard, and nearly all other photometers. The principal objections to this instrument are, first, that stars can not be compared unless they are near together, and, secondly, that faint stars can not be measured, since one half of the light is lost by polarization. The principal uses so far made of this form of photometer are in comparing the components of double stars, and in a long series of observations of the eclipses of Jupiter's satellites, which now extend over a quarter of a century and includes 768 eclipses. Instead of observing the time of disappearance, a series of measurements is made, which gives a light curve for each eclipse. Much important work might yet be done with this form of photometer, in measuring the components of doubles and of clusters, and in determining the light curves of variables which have a moderately bright star near them.

An important improvement was made in this form of photometer in 1892 by which stars as much as half a degree apart could be compared. The cones of light of two such stars are brought together by achromatic prisms, so that they can be compared as in the preceding instrument. As there is no part of the sky in which a suitable comparison star can not be found within this distance, any star may be measured with this instrument. In the hands of Professor Wendell this photometer has given results of remarkable precision. The average deviation of the result of a set of sixteen settings is about three hundredths of a magnitude. Light curves of variables can therefore be determined with great precision, and suspected variables can be divided into those that are certainly variable, and those whose changes are probably less than a tenth of a magnitude.

Another change in this instrument produced the meridian photometer. Instead of using the two cones from one object glass, two object glasses were used, mirrors being placed in front of each. In this way stars however distant can be compared. In theory this instrument leaves but little to be desired. Almost every source of error that can be suggested can be eliminated by proper reversion. As constructed, the telescope is placed horizontally, pointing east or west. One mirror reflects a star near the pole into the field, the other, a star upon the meridian. A slight motion of the mirror permits stars to be observed for several minutes before or after culmination. The first meridian photometer had objectives of only two inches aperture. With this instrument 94,476 measures were made of 4,260 stars during the years 1879 to 1882. All stars were included of the sixth magnitude and brighter, and north of declination —30°. The second instrument had objectives of four inches aperture, and permitted stars as faint as the tenth magnitude to be measured. With this instrument, during the years 1882 to 1888, 267,092 measures were made of 20,982 stars, including all the catalogue stars and all the stars of the ninth magnitude and brighter, in zones twenty minutes wide, and at intervals of

five degrees, from the north pole to declination — 20°. In 1889 the instrument was sent to South America, where 98,744 measures were made of 7,922 southern stars, extending the two preceding researches to the South Pole. On the return of the instrument to Cambridge 473,216 measures were made of 29,587 stars, including all those of the magnitude 7.5 and brighter north of declination — 30°. This work occupied the years 1891 to 1898. The instrument was again sent to Peru in 1899, and 50,816 measures were made of 5,332 stars, including all those of the seventh magnitude and brighter, south of declination — 30°. The latest research has been the measurement of a series of stars of about the fifth magnitude, one in each of a series of regions ten degrees square. Each of these stars is measured with the greatest care on ten nights. This work has been completed and published for stars north of declination — 30°, 59,428 measures having been made of 839 stars. In this count, numerous other stars have been included. Similar measures are now in progress of the southern stars, this being the third time the meridian photometer has been sent to South America. The total number of measurements exceeds a million, and the number of stars is about sixty thousand. About sixty stars can be identified with care, and each measured four times with this instrument in an hour. The probable error of a set of four settings is ± 0.08.

The principal objection to the instrument just described is the great loss of light. To measure very faint stars, another type of photometer has been devised. A twelve-inch telescope has been mounted horizontally, like the meridian photometer, and an artificial star reflected into the field. The light of this star is reduced by a wedge of shade glass until it appears equal to the star to be measured. Four hundred thousand measures have been made with this instrument during the last five years. The principal research has been the measurement of all the stars in the Bonn Durchmusterung which are contained in zones ten minutes wide and at intervals of five degrees, from the north pole to declination — 20°. Large numbers of stars of the tenth and eleventh magnitudes are thus furnished as standards of light. As the light of the object observed is unobstructed, any star however faint, if visible in the telescope, may be measured. Accordingly, many stars of the twelfth and thirteenth magnitude have been selected and measured, thus furnishing faint standards. Sequences of standard stars have been selected from coarse clusters, thus permitting estimates or measures of these bodies to be reduced to a uniform photometric scale. An investigation of great value has been carried out successfully at the Georgetown College Observatory by the Rev. J. G. Hagen, S.J. All the stars of the thirteenth magnitude and brighter have been catalogued and charted in a series of regions, each one degree square. surrounding variable stars of long period. Besides measuring the positions he has determined the relative brightness of these stars. A sequence has then been selected from each of these regions, and meas-

ured at Harvard with the twelve-inch meridian photometer, thus permitting all to be reduced to a uniform scale. As the photometer was first constructed, stars brighter than the seventh magnitude could not be measured, since they were brighter than the artificial star and could not be rendered equal to it. This difficulty was remedied by inserting a series of shades, the densest of which reduced the light by ten magnitudes. By this method, the range of the photometer may be increased indefinitely. Sirius and stars of the twelfth magnitude have been satisfactorily measured in succession. A further modification of the instrument permitted surfaces to be compared. The light of the sky at night and in the daytime, during twilight, at different distances from the moon, and different portions of the disc of the latter, have thus been compared. Measures extending over seventeen magnitudes, with an average deviation of about three hundredths of a magnitude, were obtained in this way. One light was thus compared with another six million times as bright as itself. A slight modification would permit the intrinsic brightness of the different portions of the sun's disc to be compared with that of the faintest nebulæ visible. By these instruments, the scale of photometric magnitudes has been carried as far as the thirteenth magnitude. To provide standards for fainter stars, a small appropriation was made by the Rumford Committee of the American Academy. Cooperation was secured among the directors of the Yerkes, Lick, McCormick, Halsted and Harvard Observatories. Similar photometers were constructed for all, in which an artificial star was reduced any desired amount by a photographic wedge. Telescopes of 40, 36, 26, 23 and 15 inches aperture, including the two largest refractors in the world, were thus used in the same way on the same research. The standards have all been selected, and nearly all of the measurements have been made. This furnishes a striking illustration of the advantages of cooperation, and combined organization. When these observations are reduced, we shall have standards of magnitude according to a uniform scale, for all stars from the brightest to the faintest visible in the largest telescopes at present in use. The sixty-inch reflector of the late A. A. Common has recently been secured by the Harvard Observatory. It is hoped that still fainter stars may be measured with this instrument.

We have as yet only considered the total light of a star, so far as it affects the eye. But this light consists of rays of many different wave lengths. In red stars, one color predominates, in blue, another. The true method is to compare the light of a given wave-length in different stars, and then to determine the relative intensity of the rays of different wave-lengths in different stars, or at least in stars whose spectra are of different types. This is the only true method, and fortunately spectrum photography permits it to be done. The Draper catalogue gives the class of spectrum of 10,351 stars, and the relative brightness of the light whose wave-length is 430, is determined for each. In

1891, measures were published of the relative light of rays of various wave-lengths, for a number of stars whose spectra were of the first, second and third types.

A much simpler, but less satisfactory method, is to measure the total light in a photographic image. As in the case of eye photometry, this method is open to the objection that rays of different colors are combined. Blue stars will appear relatively brighter, and red stars relatively fainter, in the photograph than to the eye. This, however, is an advantage rather than an objection, since it appears to furnish the best practical measure of the color of the stars. Relative photographic magnitudes can be obtained in a variety of ways, and the real difficulty is to reduce them to an absolute scale of magnitudes. But for this, photographic might supersede photometric magnitudes. In other respects, photography possesses all the advantages for this work that it has for other purposes, and many photometric problems are within the reach of photography, which seems hopeless by visual methods. In 1857, Professor George P. Bond, the father of stellar photography, showed that the relative light of the stars could be determined from the diameter of their photographic images. This is the method that has been generally adopted elsewhere in determining photographic magnitudes, although with results that are far from satisfactory. It is singular that although this method originated at Harvard, it is almost the only one not in use here, while a great variety of other methods have been applied to many thousands of stars, during the last eighteen years. Relative measures are obtained very satisfactorily by applying the Herschel-Argelander method to photographic images, and if these could be reduced to absolute magnitudes, it would leave but little to be desired. In the attempt to determine absolute magnitudes a variety of methods has been employed. The simplest is to form a scale by photographing a series of images, using different exposures. The image of any star may be compared directly with such a scale. To avoid the uncertain correction due to the times of exposure, different apertures may be used instead of different exposures. Another method is to attach a small prism to the objective. The image of every bright star is then accompanied by a second image a few minutes of arc distant from it, and fainter by a constant amount, as five magnitudes. Trails may be measured more accurately than circular images, and trails of stars near the pole have varying velocities, which may then be compared with one another by means of a scale. Again, images out of focus may be compared with great accuracy and rapidity by means of a photographic wedge. These comparisons promise to furnish excellent magnitudes, if they can only be reduced to the photometric scale. A catalogue giving the photographic magnitudes of 1,131 stars within two degrees of the equator, and determined from their trails, was published in 1889. Great care was taken to eliminate errors due to right ascension, so that standards in remote portions of

the sky are comparable. A similar work on polar stars at upper and lower culmination determined the photographic absorption of the atmosphere, which is nearly twice as great as the visual absorption. A catalogue of forty thousand stars of the tenth magnitude, one in each square degree, has been undertaken, and the measures are nearly complete for the portion of the sky extending from the equator to declination + 30°. These stars are compared, by means of a scale, with the prismatic companions of adjacent bright stars. Two measures have been made of images out of focus of 8,489 stars, including all of those north of declination — 20°, and brighter than the seventh magnitude. This work is being continued to the south pole. The most important completed catalogue of photographic magnitudes is the 'Cape Photographic Durchmusterung,' the monumental work of Gill and Kapteyn. 454,875 stars south of declination — 19° are included in this work. Unfortunately, the difficulty mentioned above, of reducing the magnitudes to an absolute system, has not been wholly overcome, but the work is published in a form which will permit this to be done later, if a method of reduction can be discovered. The extension of this great work to the north pole is one of the greatest needs of astronomy at the present time.

The map and catalogue of the Astrophotographic Congress, the most extensive research ever undertaken by astronomers, will not be discussed here, as it will doubtless be described by others better able than I, to explain its merits. If completed, and if the difficulty of reducing the measures of brightness to a standard scale can be overcome, it will furnish the photographic magnitudes, as well as the positions, of two million stars. Time does not permit the consideration here of certain other investigations of photographic magnitudes, such as those made at Groningen. They generally relate to a comparatively small number of stars. The suggestion that the intensity of a photographic star image be measured by the amount of light it cuts off from a thermo-pile, deserves careful study. It should give a great increase in precision, and would eliminate that tool of many defects, the human eye. No use seems to have been made so far of this method.

The next question to be considered is, what use should be made of these various measures of the light of the stars? The most obvious application of them is to variable stars. While the greater portion of the stars undergo no changes in light that are perceptible, several hundred have been found whose light changes. A natural classification seems to be that proposed by the writer in 1880. A few stars appear suddenly, and are called new stars, or novæ. They form class I. Class II. consists of stars which vary by a large amount during periods of several months. They are known as variable stars of long period. Class III. contains stars whose variations are small and irregular. Class IV. contains the variable stars of short period, and Class V. the Algol variables, which are usually of full brightness but at regular

intervals grow faint, owing to the interposition of a dark companion. Twenty years ago, when photography was first applied to the discovery of variable stars, only about two hundred and fifty of these objects were known. Since then, three remarkable discoveries have been made, by means of which their number has been greatly increased. The first was by Mrs. Fleming, who, in studying the photographs of the Henry Draper Memorial, found that the stars of the third type, in which the hydrogen lines are bright, are variables of long period. From this property she has discovered 128 new variables, and has also shown how they may be classified from their spectra. The differences between the first, second and third types of spectra are not so great as those between the spectra of different variables of long period. The second discovery is that of Professor Bailey, who found that certain globular clusters contain large numbers of variable stars of short period. He has discovered 509 new variables, 396 of them in four clusters. The third discovery, made by Professor Wolf, of Heidelberg, that variables occur in large nebulæ, has led to his discovery of 65 variables. By similar work, Miss Leavitt has found 295 new variables. The total number of variable stars discovered by photography during the last fifteen years is probably five times the entire number found visually up to the present time. Hundreds of thousands of photometric measures will be required to determine the light curves, periods and laws regulating the changes these objects undergo.

A far more comprehensive problem, and perhaps the greatest in astronomy, is that of the distribution of the stars, and the constitution of the stellar universe. No one can look at the heavens, and see such clusters as the Pleiades, Hyades and Coma Berenices, without being convinced that the distribution is not due to chance. This view is strengthened by the clusters and doubles seen in even a small telescope. We also see at once that the stars must be of different sizes, and that the faint stars are not necessarily the most distant. If the number of stars was infinite, and distributed according to the laws of chance throughout infinite and empty space, the background of the sky would be as bright as the surface of the sun. This is far from being the case. While we can thus draw general conclusions, but little definite information can be obtained, without accurate quantitative measures, and this is one of the greatest objects of stellar photometry. If we consider two spheres, with the sun as the common center, and one having ten times the radius of the other, the volume of the first will be one thousand times as great as that of the second. It will, therefore, contain a thousand times as many stars. But the most distant stars in the first sphere would be ten times as far off as those in the second sphere, and accordingly if equally bright would appear to have only one hundredth part of the apparent brightness. Expressed in stellar magnitudes, they would be five magnitudes fainter. In reality, the total number of stars of the fifth magnitude and brighter is about 1,500;

of the tenth magnitude, 373,000 instead of 1,500,000, as we should expect. An absorbing medium in space, which would dim the light of the more distant stars, is a possible explanation, but this hypothesis does not agree with the actual figures. An examination of the number of adjacent stars shows that it is far in excess of what would be expected if the stars were distributed by chance. Of the three thousand double stars in the 'Mensuræ Micrometricæ,' the number of stars optically double, or of those which happen to be in line, according to the theory of probabilities, is only about forty. This fact should be recognized in any conclusions regarding the motions of the fixed stars, based upon measures of their position with regard to adjacent bright stars.

We have here neglected all conclusions based upon the difference in composition of different stars. Photographs of their spectra furnish the material for studying this problem in detail. About half of the stars have spectra in which the broad hydrogen lines are the distinguishing feature. They are of the first type, and belong to class A of the classification of the Henry Draper Memorial. The Milky Way consists so completely of such stars that if they were removed it would not be visible. The Orion stars, forming class B, a subdivision of the first type in which the lines of helium are present, are still more markedly concentrated in the Milky Way. A large part of the other stars, forming one third of the whole, have spectra closely resembling that of the sun. They are of the second type, and form classes C and K. These stars are distributed nearly uniformly in all parts of the sky. Class M, the third type, follows the same law. Class F, whose spectrum is intermediate between classes A and C, follows the same law of distribution as classes G and K, but differs from them, if at all, in the opposite direction from class A. There, therefore, seem to be actually fewer of these stars in the Milky Way than outside of it. One class of stars, the fifth type, class O, has a very remarkable spectrum and distribution. A large part of the light is monochromatic. Of the ninety-six stars of this type so far discovered, twenty-one are in the Large Magellanic Cloud, one in the Small Magellanic Cloud, and the remainder follow the central line of the Milky Way so closely that the average distance from it is only two degrees. All of these stars, with the exception of sixteen, have been found by means of the Henry Draper Memorial.

It will be seen from the above discussion that stellar photometry in its broadest sense furnishes the means of attacking, and perhaps of solving, the greatest problem presented to the mind of man—the structure and constitution of the stellar universe, of which the solar system itself is but a minute and insignificant molecule.

THE FUNDAMENTAL CONCEPTS OF PHYSICAL SCIENCE.*

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ALL algebra, as was pointed out by von Helmholtz† nearly fifty years ago, is based upon the three following very simple propositions:

Things equal to the same thing are equal to each other.

If equals be added to equals the wholes are equal.

If unequals be added to equals the wholes are unequal.

Geometry, he adds, is founded upon a few equally obvious and simple axioms.

The science of physics, similarly, has for its foundation three fundamental conceptions: those of *mass, distance* and *time,* in terms of which all physical quantities may be expressed.

Physics, in so far as it is an exact science, deals with the relations of these so-called physical quantities; and this is true not merely of those portions of the science which are usually included under the head of physics, but also of that broader realm which consists of the entire group of the physical sciences, viz., astronomy, the physics of the heavens; chemistry, the physics of the atom; geology, the physics of the earth's crust; biology, the physics of the matter imbued with life; physics proper (mechanics, heat, electricity, sound and light).

The manner in which the three fundamental quantities L, M and T (length, mass and time) enter, in the case of a physical quantity, is given by its *dimensional formula.*

Thus the dimensional formula for an acceleration is LT^{-2} which expresses the fact that an acceleration is a velocity (a length divided by a time) divided by a time. Energy has for its dimensional formula L^2MT^{-2}; it is a force, $LT^{-2}M$ (an acceleration multiplied by a mass), multiplied by a distance.

Not all physical quantities, in the present state of our knowledge, can be assigned a definite dimensional formula, and this indicates that not all of physics has as yet been reduced to a clearly established mechanical basis. The dimensional formula thus affords a valuable criterion of the extent and boundaries of our strictly definite knowledge of physics. Within these boundaries we are on safe and easy ground and are dealing, independent of all speculation, with the relations between precisely defined quantities. These relations are

* An address at the International Congress of Arts and Science, St. Louis, September, 1904.

† Von Helmholtz, *Populäre Wissenschaftliche Vorträge*, p. 136.

mathematical and the entire superstructure is erected upon the three fundamental quantities L, M and T and certain definitions; just as geometry arises from its axioms and definitions.

Of many of those physical quantities, for which we are not as yet able to give the dimensional formula, our knowledge is precise and definite, but it is incomplete. In the case, for example, of one important group of quantities, those used in electric and magnetic measurements, we have to introduce, in addition to L, M and T, a constant factor to make the dimensional formula complete. This, the *suppressed factor* of Rücker,* is μ, the magnetic permeability, when the quantity is expressed in the electromagnetic system, and becomes k, the specific inductive capacity, when the quantity is expressed in terms of the electro-static system.

Here the existence of the suppressed factor is indicative of our ignorance of the mechanics involved. If we knew in what way a medium like iron increased the magnetic field or a medium like glass the electric field, we should probably be able to express μ and k in terms of the three selected fundamental dimensions and complete the dimensional formulæ of a large number of quantities.

Where direct mechanical knowledge ceases the great realm of physical speculation begins. It is the object of such speculation to place all phenomena upon a mechanical basis; excluding as unscientific all occult, obscure and mystical considerations.

Whenever the mechanism, by means of which phenomena are produced, is incapable of direct observation either because of its remoteness in space, as in the case of physical processes occurring in the stars, or in time, as in the case of the phenomena with which the geologist has to do, or because of the minuteness of the moving parts, as in molecular physics, physical chemistry, etc., the speculative element is unavoidable. Here we are compelled to make use of analogy. We infer the unknown from the known. Though our logic be without flaw and we violate no mathematical principle, yet are our conclusions not absolute. They rest of necessity upon *assumptions*, and these are subject to modification indefinitely as our knowledge becomes more complete.

A striking instance of the uncertainties of extrapolation and of the precarious nature of scientific assumptions is afforded by the various estimates of the temperature of the sun. Pouillet placed this temperature between 1461° C. and 1761° C.; Secchi at 5,000,000°; Ericsson at 2,500,000°. The newer determinations,† of the temperature of the surface are, to be sure, in better agreement. Le Chatelier finds it to be 7600°; Paschen 5400°; Warburg 6000°. Wilson and Gray publish as their corrected result, 8000°. The estimate of the internal temperature is of a more speculative character. Schuster's computation gives

* Rücker, *Philos. Mag.*, 27, p. 104, 1889.

† See Arrhenius. *Kosmische Physik*, p. 131.

6,000,000° to 15,000,000°; that of Kelvin 200,000,000°; that of Ekholm 5,000,000°.

Another interesting illustration of the dangers of extrapolation occurs in the history of electricity. Faraday, starting from data concerning the variation between the length of electric sparks through air with the difference of potential, made an interesting computation of the potential difference between earth and sky necessary to discharge a cloud at a height of one mile. He estimated the difference of potential to be about 1,000,000 volts. Later investigations of the sparking distance have, however, shown this function to possess a character quite different from that which might have been inferred from the earlier work, and it is likely that Faraday's value is scarcely nearer the truth than was the original estimate of the temperature of the sun, mentioned above.

Still another notable instance of the errors to which physical research is subject when the attempt is made to extend results beyond the limits established by actual observation occurs in the case of the measurements of the infra-red spectrum of the sun by Langley. His beautiful and ingenious device, the bolometer, made it possible to explore the spectrum to wave-lengths beyond those for which the law of dispersion of the rock-salt prism had at that time been experimentally determined. Within the limits of observation the dispersion showed a curve of simple form, tending apparently to become a straight line as the wave-length increased. There was nothing in the appearance of the curve to indicate that it differed in character from the numerous empirical curves of similar type employed in experimental physics, or to lead even the most experienced investigator to suspect values for the wave-length derived from an extension of the curve. The wave-lengths published by Langley were accordingly accepted as substantially correct by all other students of radiation, but subsequent measurements of the dispersion of rock salt at the hands of Rubens and his coworkers showed the existence of a second sudden and unlooked-for turn of the curve just beyond the point at which the earlier determinations ceased; and in consequence Langley's wave-lengths and all work based upon them are now known to be not even approximately accurate. The history of physics is full of such examples of the dangers of extrapolation, or, to speak more broadly, of the tentative character of most of our assumptions in experimental physics.

We have then two distinct sets of physical concepts. The first of these deals with that positive portion of physics the mechanical basis of which, being established upon direct observation, is fixed and definite, and in which the relations are as absolute and certain as those of mathematics itself. Here speculation is excluded. Matter is simply one of the three factors which enters, by virtue of its mass, into our formulæ for energy, momentum, etc. Force is simply a quantity of which we need to know only its magnitude, direction, point of appli-

cation and the time during which it is applied. The Newtonian conception of force—the producer of motion—is adequate. All troublesome questions as to how force acts, of the mechanism by means of which its effects are produced are held in abeyance.

Speculative physics, to which the second set of concepts belong, deals with those portions of the science for which the mechanical basis has to be imagined. Heat, light, electricity and the science of the nature and ultimate properties of matter belong to this domain.

In the history of the theory of heat we find one of the earliest manifestations of a tendency so common in speculative physics that it may be considered characteristic; the assumption of a medium. The medium in this case was the so-called *imponderable* caloric; and it was one of a large class, of which the two electric fluids, the magnetic fluid, etc., were important members.

The theory of heat remained entirely speculative up to the time of the establishment of the mechanical equivalent of heat by Joule. The discovery that heat could be measured in terms of work, injected into thermal theory the conception of energy and led to the development of thermodynamics.

Generalizations of the sort expressed by Tyndall's phrase, *heat a mode of motion,* follow easily from the experimental evidence of the part which energy plays in thermal phenomena, but the specification of the precise mode of motion in question must always depend upon our views concerning the nature of matter, and can emerge from the speculative stage only, if ever, when our knowledge of the mechanics of the constitution of matter becomes fixed. The problem of the mechanism by which energy is stored or set free rests upon a similar speculative basis.

These are proper subjects for theoretical consideration, but the dictum of Rowland* that we get out of mathematical formulæ only what we put into them should never be lost from sight. So long as we put in only assumptions we shall take out hypotheses, and useful as these may prove, they are to be regarded as belonging to the realm of scientific speculation. They must be recognized as subject to modification indefinitely as we, in consequence of increasing knowledge, are led to modify our assumptions.

The conditions with which the physicist has to deal in his study of optics are especially favorable to the development of the scientific imagination, and it is in this field that some of the most remarkable instances of successful speculative work are to be found. The emission theory died hard and the early advocates of the undulatory theory of light were forced to work up with a completeness, probably without parallel in the history of science, the evidence, necessarily indirect, that in optics we have to do with a wave-motion. The standpoint of

* Rowland, president's address to the American Physical Society, 1900.

optical theory may be deemed conclusive, possibly final, so far as the general proposition is concerned that it is the science of a wave-motion. In a few cases, indeed, such as the photography of the actual nodes of a standing waves ystem, by Wiener, we reach the firm ground of direct observation.

Optics has nevertheless certain distinctly speculative features. Wave-motion demands a medium. The enormous velocity of light excludes known forms of matter; the transmission of radiation in vacuo and through outer space from the most remote regions of the universe, and at the same time through solids such as glass demands that this medium shall have properties very different from that of any substance with which chemistry has made us acquainted.

The assumption of a medium is, indeed, an intellectual necessity and the attempt to specify definitely the properties which it must possess in order to fulfill the extraordinary functions assigned to it has afforded a field for the highest display of scientific acumen. While the problem of the mechanism of the luminiferous ether has not as yet met with a satisfactory solution, the ingenuity and imaginative power developed in the attack upon its difficulties command our admiration.

Happily the development of what may be termed the older optics did not depend upon any complete formulation of the mechanics of the ether. Just as the whole of the older mechanics was built up from Kepler's laws, Newton's laws of motion, the law of gravitational attraction, the law of inverse squares, etc., without any necessity of describing the mechanics of gravitation or of any force, or of matter itself, so the system of geometrical relations involved in the consideration of reflection and refraction, diffraction, interference and polarization was brought to virtual completion without introducing the troublesome questions of the nature of the ether and the constitution of matter.

Underlying this field of geometrical optics or what I have just termed the older optics are, however, a host of fundamental questions of the utmost interest and importance, the treatment of which depends upon molecular mechanics and the mechanics of the ether. Our theories as to the nature and causes of radiation, of absorption and of dispersion, for example, belong to the newer optics and are based upon our conceptions of the constitution of matter; and since our ideas concerning the nature of matter, like our knowledge of the ether, is purely speculative, the science of optics has a doubly speculative basis. One type of selective absorption, for example, is ascribed to resonance of the particles of the absorbing substance, and our modern dispersion theories depend upon the assumption of natural periods of vibration of the particles of the refracting medium of the same order of frequency as that of the light waves. When the frequency of the waves falling upon a substance coincides with the natural period of vibration of the particles of the latter we have selective absorption, and accom-

panying it anomalous dispersion. For these and numerous other phenomena no adequate theory is possible which does not have its foundation upon some assumed conception as to the constitution of matter.

The development of the modern idea of the ether forms one of the most interesting chapters in the history of physics. We find at first a tendency to assume a number of distinct media corresponding to the various effects (visual, chemical, thermal, phosphorescent, etc.) of light waves, and later the growth of the conception of a single medium, the luminiferous ether.

In the development of electricity and magnetism, meantime, the assumption of media was found to be an intellectual necessity without which no definite philosophy of the phenomena was possible. At first there was the same tendency to a multiplicity of media—there were the positive and negative electric fluids, the magnetic fluid, etc. Then there grew up in the fertile mind of Faraday that wonderful fabric of the scientific imagination, the electric field; the conception upon which all later attempts to form an idea of a thinkable mechanism of electric and magnetic action have been established.

It is the object of science, as has been pointed out by Ostwald, to reduce the number of hypotheses, and the highest development would be that in which a single hypothesis served to elucidate the relations of the entire universe. Maxwell's discovery that the whole theory of optics is capable of expression in terms identical with those found most convenient and suitable in electricity, in a word that optics may be treated simply as a branch of electromagnetics, was the first great step towards such a simplification of our fundamental conceptions. This was followed by Hertz's experimental demonstration of the existence of artificially produced electromagnetic waves in every respect identical with light waves, an achievement which served to establish upon a sure foundation the conception of a single medium. The idea of one universal medium as the mechanical basis for all physical phenomena was not altogether new to the theoretical physicist but the unification of optics and electricity did much to strengthen this conception.

The question of the ultimate structure of matter, as has already been pointed out, is also speculative in the sense that the mechanism upon which its properties are based is out of the range of direct observation. For the older chemistry and the older molecular physics the assumption of an absolutely simple atom and of molecules composed of comparatively simple groupings of such atoms sufficed. Physical chemistry and that new phase of molecular physics which has been termed the physics of the ion demand the breaking up of the atom into still smaller parts and the clothing of these with an electric charge. The extreme step in this direction is the suggestion of Larmor that the electron is a 'disembodied charge' of negative electricity.

Since, however, in the last analysis, the only conception having a

definite and intelligible mechanical basis which physicists have been able to form of an electric charge is that which regards it as a phenomenon of the ether, this form of speculation is but a return under another name to views which had earlier proved attractive to some of the most brilliant minds in the world of science, such as Helmholtz and Kelvin. The idea of the atom, as a vortex motion of a perfect fluid (the ether), and similar speculative conceptions, whatever be the precise form of mechanism imagined, are of the same class as the moving electric charge of the later theorists.

Lodge* in a recent article in which he attempts to voice in a popular way the views of this school of thought says:

"*Electricity under strain constitutes 'charge'; electricity in locomotion constitutes light. What electricity itself is we do not know, but it may, perhaps, be a form or aspect of matter. . . . Now we can go one step further and say, matter is composed of electricity and of nothing else. . . .*"

If for the word *electricity* in this quotation from Lodge we substitute *ether,* we have a statement which conforms quite as well to the accepted theories of light and electricity as his original statement does to the newer ideas it is intended to express.

This reconstructed statement would read as follows:

Ether under strain constitutes 'charge'; *ether* in locomotion constitutes current and magnetism; *ether* in vibration constitutes light. What *ether* itself is we do not know, but it may, perhaps, be a form or aspect of matter. Now we can go one step further and say: Matter is composed of *ether* and of nothing else.

The use of the word electricity, as employed by Lodge and others, is now much in vogue, but it appears to me unfortunate. It would be distinctly conducive to clearness of thought and an avoidance of confusion to restrict the term to the only meaning which is free from criticism; that in which it is used to designate the science which deals with electrical phenomena.

The only way in which the noun *electricity* enters, in any definite and legitimate manner into our electrical treatises is in the designation of Q in the equations

$$Q=\int Idt,\ C=Q/E,\ W=QE, \text{ etc.}$$

Here we are in the habit—whether by inheritance from the age of the electric fluid, by reason of the hydrodynamic analogy or as a matter of convention or of convenience merely—of calling Q the *quantity of electricity.*

Now Q is 'charge' and its unit the coulomb is unit charge. The alternative expression, *quantity of electricity,* is a purely conventional designation and without independent physical significance. It owes its

* Lodge, *Harper's Magazine,* August, 1904, p. 383.

prevalence among electricians to the fact that by virtue of long familiarity we prefer to think in terms of matter, which is tangible, rather than of ether.

Charge is to be regarded as fundamental, and its substitute, quantity of electricity, as merely an artificial term of convenience; because of the former we have a definite mechanical conception, whereas we can intelligently define a quantity of electricity only in terms of *charge*.

In the science of heat the case differs in that the term heat is used, if not as precisely synonymous with energy, at least for a quantity having the same dimensions as energy and having as its unit the erg. It might easily have happened, as has happened in electrical theory, that the ancient notion of a *heat substance* should survive, in which case we should have had for the quantity of heat not something measured in terms of energy, but, as in the case of electricity, one of the terms which enter into our expression for energy. We should then have had to struggle continually, in thermo-dynamics, as we now do in electrical theory, against the tendency to revert to an antiquated and abandoned view.

It would, I can not but think, have been fortunate had the word electricity been used for what we now call electrical energy; using *charge*, or some other convenient designation, for the quantity Q. That aspect of the science in accordance with which we regard it as a branch of energetics in which movements of the ether are primarily involved would have been duly emphasized. We should have been quit forever of the bad notion of electricity as a medium, just as we are already freed from the incubus of heat as a medium. We should have had *electricity—a mode of motion* (or stress) of the ether as we have *heat—a mode of motion* (of matter). When our friends asked us: 'What is electricity?' we should have had a ready answer for them instead of a puzzled smile.

One real advance which has been attained by means of the theory of ionization, and it is of extreme significance and of far-reaching importance, consists in the discovery that electrification or the possession of charge, instead of being a casual or accidental property, temporarily imparted by friction or other process, is a fundamental property of matter. According to this newer conception of matter, the fruit of the ionic theory, the ultimate parts of matter, are electrically charged particles. In the language of Rutherford:*

> It must then be supposed that the process of ionization in gases consists in a removal of a negative corpuscle or electron from the molecule of gas. At atmospheric pressure this corpuscle immediately becomes the center of an aggregation of molecules which moves with it and *is* the negative ion. After removal of the negative ion the molecule retains a positive charge and probably also becomes the center of a cluster of new molecules.
>
> The *electron* or *corpuscle* is the body of smallest mass yet known to science.

* Rutherford, 'Radioactivity,' p. 53, 1904.

It carries a negative charge of 3.4×10^{-10} electrostatic units. Its presence has only been detected when in rapid motion, when it has for speeds up to about 10^{10} cms. a second, an apparent mass m given by $e/m = 1.86 \times 10^{7}$ electromagnetic units. This apparent mass increases with the speed as the velocity of light is approached.

At low pressures the electron appears to lose its load of clustering molecules, so that finally the negative ion becomes identical with the electron or corpuscle and has a mass, according to the estimates of J. J. Thomson, about one thousandth of that of the hydrogen atom. The positive ion is, however, supposed to remain of atomic size even at low pressures.

The ionic theory and the related hypothesis of electrolytic dissociation afford a key to numerous phenomena concerning which no adequate or plausible theories had hitherto been formed. By means of them explanations have been found, for example, of such widely divergent matters as the positive electric charge known to exist in the upper atmosphere and the perplexing phenomena of fluorescence.

The evidence obtained by J. J. Thomson and other students of ionization, that electrons from different substances are identical, has greatly strengthened the conviction which for a long time has been in process of formation in the minds of physicists, that all matter is in its ultimate nature identical. This conception, necessarily speculative, has been held in abeyance by the facts, regarded as established and lying at the foundation of the accepted system of chemistry, of the conservation of matter and the intransmutability of the elements. The phenomena observed in recent investigations of radioactive substances have, however, begun to shake our faith in this principle.

If matter is to be regarded as a product of certain operations performed upon the ether there is no theoretical difficulty about transmutation of elements, variation of mass or even the complete disappearance or creation of matter. The absence of such phenomena in our experience has been the real difficulty, and if the views of students of radioactivity concerning the transformations undergone by uranium, thorium and radium are substantiated, the doctrines of the conservation of mass and matter which lie at the foundation of the science of chemistry will have to be modified. There has been talk of late of violations of the principle of the conservation of energy in connection with the phenomena of radio-activity, but the conservation of matter is far more likely to lose its place among our fundamental conceptions.

The development of physics on the speculative side has led, then, to the idea, gradually become more definite and fixed, of a universal medium, the existence of which is a matter of inference. To this medium properties have been assigned which are such as to enable us to form an intelligible, consistent conception of the mechanism by means of which phenomena, the mechanics of which is not capable of direct observation, may be logically considered to be produced. The

great step in this speculation has been the discovery that a single medium may be made to serve not only for the numerous phenomena of optics, but, without ascribing to it any characteristics incompatible with a luminiferous ether, is equally available for the description and explanation of electric and magnetic fields, and finally may be made the basis for intelligible theories of the structure of matter.

To many minds this seemingly universal adaptability of the ether to the needs of physics almost removes it from the field of speculation; but it should not be forgotten that a system, entirely imaginary, may be devised, which fits all the known phenomena and appears to offer the only satisfactory explanation of the facts, and which subsequently is abandoned in favor of other views. The history of physics is full of instances where a theory is for a time regarded as final on account of its seeming completeness, only to give way to something entirely different.

In this consideration of the fundamental concepts I have attempted to distinguish between those which have the positive character of mathematical laws and which are entirely independent of all theories of the ultimate nature of matter and those which deal with the latter questions and which are essentially speculative. I have purposely refrained from taking that further step which plunges us from the heights of physics into the depths of philosophy.

With the statement that science in the ultimate analysis is nothing more than *an attempt to classify and correlate our sensations* the physicist has no quarrel. It is, indeed, a wholesome discipline for him to formulate for himself his own relations to his science in terms such as those which, to paraphrase and translate very freely the opening passages of his recent 'Treatise on Physics,' Chwolson* has employed.

> For every one there exist two worlds, an inner and an outer, and our senses are the medium of communication between the two. The outer world has the property of acting upon our senses, to bring about certain changes, or, as we say, to exert certain stimuli.
>
> The inner world, for any individual, consists of all those phenomena which are absolutely inaccessible (so far as direct observation goes) to other individuals. The stimulus from the outer world produces in our inner world a subjective perception which is dependent upon our *consciousness*. The subjective perception is made objective, viz., is assigned *time* and *place* in the outer world and given a name. The investigation of the processes by which this objectivication is performed is a function of philosophy.

Some such confession of faith is good for the man of science; *lest he forget;* but once it is made he is free to turn his face to the light once more, thankful that the *investigation of objectivication* is, indeed, *a function of philosophy* and that the only speculations in which he, as a physicist, is entitled to engage are those which are amenable at every step to mathematics and to the equally definite axioms and laws of mechanics.

* Chwolson, 'Physik,' Vol. I., Introduction.

THE METHODS OF THE EARTH-SCIENCES.*

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IT is my assigned task to review the methods of the earth-sciences. The technical processes of the constituent sciences are peculiar to each and are inappropriate subjects for discussion before this composite assemblage; but the fundamental methods of intellectual procedure are essentially common to all the earth-sciences, and to these the address will confine itself.

That which passes under the name earth-science is not all *science* in the strict sense of the term. Not a little consists of generalizations from incomplete data, of inferences hung on chains of uncertain logic, of interpretations not beyond question, of hypotheses not fully verified and of speculation none too substantial. A part of the mass is true science, a part is philosophy, as I would use the term, a part is speculation, and a part is yet unorganized material. However, I like to think of the aggregate, not as an amorphous mixture of science, philosophy and speculation, but as a rather definite aggregation of these, not unlike that of the earth itself. The great mass of our subject-material may be regarded as a lithosphere of solid facts. Around this gathers an atmosphere of philosophy, rather dense near the contact zone, but thinning away into tenuous speculation in the outer regions. For myself, I like to think of the nucleus as solid and firm throughout, not as a thin fractured crust floating on a fiery liquid of plutonian suggestiveness. I like to think of the philosophic and speculative atmosphere as no mere gas-zone of forty-five miles' depth, as of old, but as an envelope of intense kinetic life, in the denser zone, where the logical molecules touch one another with marvelous frequency, and where there is frictional contact with the solid but rather inert lithosphere. In the outer tenuous zone, the molecular flights are freer and the excursions are without assignable limits. I believe an appropriate atmosphere of philosophy is as necessary to the wholesome intellectual life of our sciences as is the earth's physical atmosphere to the life of the planet. None the less, it must ever be our endeavor to reduce speculation to philosophy, and philosophy to science. For the perpetuation of the necessary philosophic atmosphere, we may safely trust to the evolution of new problems concurrently with the solution of the old.

But granting the importance of the philosophic element, we doubt-

* An address at the International Congress of Arts and Science, St. Louis, September, 1904.

less agree without hesitation that the solid products of accurate and complete observation, natural or experimental, are the bed-rock of our group of sciences. The first great object sought by laudable methods is, therefore, the promotion of the most accurate, searching, exhaustive and unbiased observation that is possible. One of the primary efforts in behalf of our sciences, therefore, was naturally directed to the task cf promoting the best observational work. It was soon discovered that two chief dangers threatened the worker—bias and incompleteness. To guard against the first there was evolved

The Method of Colorless Observation.

Under its guidance, the observer endeavors to keep his mind scrupulously free from prepossessions and favored views. However tensely he may strain his observing powers to see what is to be seen, he seeks solely a record of facts uncolored by preferences or prejudices. To this end, he restrains himself from theoretical indulgence, and modestly contents himself with being a recorder of nature. He does not presume to be its interpreter and prophet. At length, in the office, he gathers his observations into an assemblage, with such inferences and interpretations as flow from them spontaneously, but even then he guards himself against the prejudices of theoretical indulgence.

Laudable as this method is in its avoidance of partiality, it is none the less seriously defective. No one who goes into the field with a mind merely receptive, or merely alert to see what presents itself, however nerved to a high effort, will return laden with all that might be seen. Only a part of the elements and aspects of complex phenomena present themselves at once to even the best observational minds. Some parts of the complex are necessarily obscure. Some of the most significant elements are liable to be unimpressive. These unobtrusive but yet vital elements will certainly escape observation unless it is forced to seek them out, and to seek them out diligently, acutely and intensely. To make a reasonably complete set of observations, the mind must not only see what spontaneously arrests its attention, but it must immediately draw out from what it observes inferences, interpretations, and hypotheses to promote further observations. It must at once be seen that if a given inference is correct, certain collateral phenomena must accompany it. If another inference be correct, certain other phenomena must accompany it. If still a third interpretation be the true one, yet other phenomena must be present to give proof of it. Once these suggestions have arisen, the observer seeks out the phenomena that discriminate between them, and, under such stimulus, phenomena that would otherwise have wholly escaped attention at once come intc view because the eye has now been focused for them. It may be affirmed with great confidence that without the active and instantaneous use of these concurrent processes the observer will rarely, if ever, record the whole of any one set of significant ele-

ments, much less the whole of all sets. His record will contain incomplete parts of different sets of significant elements, *but no complete set of any one.* The obscure factors of each set are quite sure to be overlooked and the obtrusive factors of several sets indiscriminately commingled. The method of colorless observation is thus seriously defective in the completeness of its products, while it successfully guards them from bias.

Standing over against it, in strong contrast, is the method which at once endeavors to seek out and put together the phenomena that are thought to be significant. This leads promptly to the construction of a theory or an explanation which soon comes to guide the work and gives rise to

The Method of the Ruling Theory.

The chief effort here centers on an elucidation of phenomena, not on an exhaustive determination of the facts. Properly enough the crown of the work is the end, explanation is brought to the forefront and eagerly made the immediate end of endeavor. As soon as a phenomenon is presented, a theory of elucidation is framed. Laudable enough in itself, the theory is liable to be framed before the phenomena are fully and accurately observed. The elucidation is likely to embrace only the more obtrusive phenomena, not the full complement of the obtrusive and the unimpressive. The field is quite likely to present many repetitions of the leading phenomena and a theory framed to fit those that first arrest attention naturally fits the oft-recurrent phenomena of the same class. While there may be really no new evidence, nor any real test, nor any further inquiry into the grounds of the theory, its repeated application with seeming success leads insidiously to the delusion that it has been strengthened by additional investigation. Unconsciously then it begins to direct observation to the facts it so happily elucidates. Unconsciously the facts to which it gives no meaning become less impressive and fall into neglect. Selective observation creeps insidiously in and becomes a persistent habit. Soon also affection is awakened with its blinding influence. The authorship of an original explanation that seems successful easily begets fondness for one's intellectual child. This affection adds its alluring influence to the previous tendency toward an unconscious selection. The mind lingers with pleasure upon the facts that fall happily into the embrace of the theory, and feels a natural indifference toward those that assume a refractory or meaningless attitude. Instinctively, there is a special searching-out of phenomena that support the theory; unwittingly also there is a pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory. When these biasing tendencies set in, the mind soon glides into the partiality of paternalism, and the theory rapidly rises to a position of control. Unless it happens to be the true one, all hope of the best results is gone. The defects of this method are obvious and grave.

It is safe to say, however, that under this method, with all its defects, many facts will be gathered that an observer of colorless attitude would have quite overlooked. The reverse may doubtless also be said. An effort to avoid the dangers at once of the colorless Scylla and the biasing Charybdis gave rise to

The Method of the Working Hypothesis.

This may be regarded as the distinctive feature of the methodology of the last century. This differs from the method of the ruling theory in that the working hypothesis is made a means of determining facts, not primarily a thesis to be established. Its chief function is the suggestion and guidance of lines of inquiry; inquiry not for the sake of the hypothesis, but for the sake of the facts and their final elucidation. The hypothesis is a mode rather than an end. Under the ruling theory, the stimulus is directed to the finding of facts for the support of the theory. Under the working hypothesis, the facts are sought for the purpose of ultimate induction and demonstration, the hypothesis being but a means for the more ready development of facts and their relations, particularly *their relations.*

It will be seen that the distinction is somewhat subtile. It is rarely if ever perfectly sustained. A working hypothesis may glide with the utmost ease into a ruling theory. Affection may as easily cling about a beloved intellectual child under the name of a working hypothesis as under any other, and may become a ruling passion. The moral atmosphere associated with the working hypothesis, however, lends some good influence toward the preservation of its integrity. The author of a working hypothesis is not presumed to father or defend it, but merely to use it for what it is worth.

Conscientiously followed, the method of the working hypothesis is an incalculable advance upon the method of the ruling theory, as it is also upon the method of colorless observation; but it also has serious defects. As already implied, it is not an adequate protection against a biased attitude. Even if it avoids this, it tends to narrow the scope of inquiry and direct it solely along the lines of the hypothesis. It undoubtedly gives acuteness, incisiveness and thoroughness in its own lines, but it inevitably turns inquiry away from other lines. It has dangers therefore akin to its predecessor, the ruling theory.

A remedy for these dangers and defects has been sought in

*The Method of Multiple Working Hypotheses.**

This differs from the method of the simple working hypothesis in that it distributes the effort and divides the affections. It is thus in some measure protected against the radical defects of the two previous methods. The effort is to bring up into distinct view every rational explanation of the phenomenon in hand and to develop into working

* In this sketch I have drawn freely upon my paper on 'The Method of Multiple Working Hypotheses,' *Journ. Geol.*, V., 1897.

form every tenable hypothesis of its nature, cause or origin, and to give to each of these a due place in the inquiry. The investigator thus becomes the parent of a family of hypotheses; and by his paternal relations to all is morally forbidden to fasten his affections unduly upon any one. In the very nature of the case, the chief danger that springs from affection is counteracted. Where some of the hypotheses have been already proposed and used, while others are the investigator's own creation, a natural tendency to bias arises, but the right use of the method requires the impartial adoption of all into the working family. The investigator thus at the outset puts himself in cordial sympathy and in the parental relations of adoption, if not of authorship, with every hypothesis that is at all applicable to the case under investigation. Having thus neutralized, so far as may be, the partialities of his emotional nature, he proceeds with a certain natural and enforced erectness of mental attitude to the inquiry, knowing well that some of the family of hypotheses must needs perish in the ordeal of crucial research, but with a reasonable expectation that more than one of them may survive, since it often proves in the end that several agencies were conjoined in the production of the phenomenon. Honors must often be divided between hypotheses. In following a single hypothesis, the mind is biased by the presumptions of the method toward a single explanatory conception. But an adequate explanation often involves the coordination of several causes. This is especially true when the research deals with complicated phenomena such as prevail in the field of the earth-sciences. Not only do several agencies often participate, but their proportions and relative importance vary from instance to instance in the same class of phenomena. The true explanation is therefore necessarily multiple, and often involves an estimate of the measure of participation of each factor. For this the simultaneous use of a full staff of working hypotheses is demanded. The method of the single working hypothesis is here incompetent.

The reaction of one hypothesis upon another leads to a fuller and sharper recognition of the scope of each. Every added hypothesis is quite sure to call forth into clear recognition neglected aspects of the phenomena. The mutual conflicts of hypotheses whet the discriminative edge of each. The sharp competition of hypotheses provokes keenness in the analytic processes and acuteness in differentiating criteria. Fertility in investigative devices is a natural sequence. If therefore an ample group of hypotheses encompass the subject on all sides, the total outcome of observation, of discrimination and of recognition of significance and relationship is full and rich.

Closely allied to the method of multiple working hypotheses is

The Method of Multiple Series.

In many of the more complex problems of the earth-sciences the basal facts are but imperfectly determined, *e. g.*, the rate of rise of

internal temperature, the rigidity of the earth's body, the thermal conductivity of the earth's interior, the amount of the earth's shrinkage, the extent of lateral thrust in the formation of folded mountains and many others, indeed most others. There is need to deal with these problems notwithstanding the imperfection of the basal data, for in many cases these must long remain imperfect. Moreover, there is need to treat these problems tentatively to determine what fundamental facts are really needed, how these can best be secured, and with what precision they must be determined. Preliminary trial may save much tedious and expensive experimentation. It is as foolish to cultivate sterile soil in science as in agriculture, and preliminary tests may show that given soils are necessarily sterile. In many cases, all the needs of the problem may be met by a multiple series of assumptions covering the full range of a probable fact. In most cases it is easy to see that the value of a given fundamental factor can not range beyond certain extremes on either hand. If a series of values ranging from the one extreme to the other be used simultaneously in the inquiry, the full range of results dependent on this factor may be covered. In some inquiries this serves as well as if the exact truth were known, for whatever the assignable value, certain deductions can not stand. In other cases, it will be shown that a very slight change in the value of the basal factor will wholly change the outcome, and hence that extremely accurate determinations must be made before any trustworthy solution can be reached. Expensive determinations in the first case are folly; very accurate determinations in the second are to be sought at any cost. Conclusions on imperfect data in the one case are perfectly safe; conclusions without precise determinations in the other are folly. It is to be hoped that, with the wider adoption of the method of multiple series, tables of serial determinations covering the data of the more vital phenomena of the earth-sciences will be constructed, as tables of physical constants now are.

The Method of Regenerative Hypotheses.

In the method of multiple hypotheses, the members of the group are used simultaneously and are more or less mutually exclusive, or even antagonistic. Supplementary to this method is the use of a *succession* of hypotheses related genetically to one another. In this the results of an inquiry under the first hypothesis give rise to the assumptions of the succeeding hypothesis. The precise conclusions of the first inquiry are not made the assumptions of the second, for the process would then be little more than repetitive, but the revelations and intimations, perhaps the incongruities and incompatibilities of the first results beget, by their suggestiveness, the basis of the second. The latter is the offspring of the former, but between parent and offspring there is mutation with an evolutionary purpose. A cruder first attempt generates a more highly organized and specialized work-

ing scheme fitted to the new state of knowledge developed. The method is specially applicable to elaborate inquiries, particularly those in which the premises are imperfect and a long logical chain is hung upon them. The discussions of our great fundamental conceptions furnish the best examples, chiefly examples of the lack of a systematic regenerative method. Among these, two general classes may be recognized, (1) those of a rather rigorous type, as, for a distinguished example, the researches of George Darwin on tidal reaction and the history of the earth and moon, and (2) those of a looser and sometimes rather metaphysical type, which I shall try to illustrate by the doctrine of determinism. In all cases, *assumptions* are made the basis of the procedure. Absolute premises are not available. Taking its start from these assumptions, the process pursues a long course and at the end conclusions of great import are often drawn. Usually the process rests there, and in this lies a serious shortcoming. It should give rise to a new process of a higher order. Not seldom, a critical study of the results will reveal features that were not recognized nor suspected in the original assumptions, though really there. Out of these revelations should grow new assumptions and a new process. The second conclusion may in like manner betray unsuspected qualities and these should beget still other assumptions, and so the procedure should continue until the field is exhausted.

To choose a specific illustration is not a little delicate, for to be most familiar it must be of the negative type, but I fear such an illustration is the only way to clearly convey the meaning here intended. I therefore venture to choose one so eminent and so admirable, even with its limitations, that any suggestion of shortcoming will in no wise dim the luster of a great achievement. In the classic investigations of George Darwin on tides and their astronomic consequences, a viscous earth is assumed as the starting-point, with properties such that the tidal protuberance is carried forward by the rotation of the earth to the point which gives the maximum effect on the motions of the earth and moon. These assumptions run potentially through the whole train of brilliant mathematical deduction. At the end of the inquiry, or if not of this particular inquiry, at least of collateral inquiries, the conclusion is reached that the earth is a rigid body comparable to steel. Between such a rigid body and such a viscous earth as was assumed at the outset of the inquiry, there is a seeming incongruity. This, under the regenerative method, suggests a new investigation on the assumption that the earth is a very rigid body, with the further assumption that it has high elasticity of form, such that its protuberance may perhaps not be carried forward to the degree previously postulated. These new assumptions are the more imperative, because they are supported by inquiries based on quite independent lines. In framing the new hypothesis an advance in detail and in organization is to be sought on the evolutionary principle already in-

dicated. If the earth as a whole is as rigid as steel, and the outer part is, as we know, formed of rock much less rigid than steel, the interior must be much more rigid than steel and there must be a differential distribution of rigidity. The new inquiry may then well start with the assumption of increasing rigidity toward the center. Postulating an earth so constituted, a first step of the regenerated inquiry might well be an effort to learn not only the amount of the tidal protuberance, but also the *position* of the protuberance, since its position is as essential as its amount in influencing the motions of the earth and moon. As a geologist I venture to entertain the belief that exhaustive inquiry on such regenerative lines would bring forth results in harmony with geological evidences, with which the well-known conclusions heretofore reached seem to be at fatal variance.

The earth-sciences are not purely physical sciences. They concern themselves with life and with mentality, as well as with rocks, ocean and atmosphere. Our group is exceptionally comprehensive in the range of its subjects. Our methods should hence be such as to encompass the whole field. They should give us ultimately a complete working system of thought relative to all the earth is or holds. In some sense the earth sciences must come to comprehend the essentials of all the sciences. At least as much as any other scientists we are interested in the fundamental assumptions of all the sciences and in their consistent application. To touch hastily this broader field, I choose a second illustration of the method of regenerative hypotheses from the relations between the assumptions of science and the conclusions of science.

As our working basis, we assume that our perceptions represent reality, when duly directed and corrected, but that error and illusion lurk on all sides and must be scrupulously avoided. We assume that we are capable of detecting error and of demonstrating truth; and that, as requisite means, we have choice, and some measure of volitional command over ourselves and over nature.

Starting thus with assumptions that embrace choice and the possibility of error, and going out into physical research, most of us have concluded that antecedents are followed rigorously by their consequents. Going out a step further into the chemico-biological field and noting the close interrelations between physical and vital phenomena, many of us have been led to a belief in their ultimate identity. Going out a step further into the mental field, not a few of us have concluded that an unvarying sequence of antecedents and consequents reigns here also. But this seems to contradict the assumptions with which we started. Our primary assumptions embraced choice, volitional control, and the alternative of reaching truth or falling into error according to our self-directed discrimination.

What is to be done in the face of this seeming contradiction? The method of regenerative hypotheses answers that a new set of assump-

tions begotten of the contradictory conclusion should be made the basis of a new inquiry, and if possible of a new working hypothesis. Instead of the usual assumption of choice, and of the possible alternative of reaching truth or falling into error, let the assumption be that all acts of the mind are parts of a rigorous chain of antecedents and consequents. Let it be assumed that no swerving from the predetermined sequences is possible, that every thought and every act follows its antecedents with absolute rigor, no real choice, or volition, or alternative between accuracy and error being possible.

Let this set of assumptions be tried as a working hypothesis. If investigation be possible under it, let such investigation cover the whole ground of what we call truth and error. Let a distinction be drawn between absolutely predetermined mental actions corresponding to truthfulness on the one hand, and falsity on the other, if this be possible, and out of the former let science be constructed and let it be shown *why it is science,* and let the latter be disposed of in some suitable way. In other words, let the doctrine of determinism *be put into workable form,* and carried into effect in all its applications, with every step true to the primary assumptions. If this can be done successfully, we shall have a wholly new working basis for the production of science, with new criteria of science. If it can not be done and the hypothesis of determinism is unworkable, let it be cast aside like any other unworkable hypothesis. Whatever metaphysicians may think of an unworkable scheme, scientific investigators may as well send it to the junk shop.

Huxley once delivered himself of an able exposition of determinism. It was severely criticized by a fellow countryman who seemed to Huxley to have dealt with him unjustly, and he poured out the vials of his rhetorical wrath upon him as only Huxley could. But if determinism be true, I do not see how Huxley's critic could have swerved by a turn of a phrase from what he wrote, and Huxley's wrath was not more consistent than that assigned to Xerxes when he lashed the stormy Hellespont because it thwarted his purpose. But in this I may be wholly wrong. *Let determinism prove itself by giving rise to a complete and systematic working hypothesis.*

Whether this can be done or not, let any other basal assumptions suggested by the inquiry be made the ground of like attempts and be developed into full working hypotheses, if possible, and so continue the effort until the whole field is covered. Let it be seen what can and what can not be put into the form of a working system.

In this second illustration of the method of regenerative hypotheses, I have touched questions not usually thought to belong to the earth-sciences. It is none the less true that they are basal to the earth-sciences, as they are to all science, and to all true philosophy as well. The earth-sciences are entitled to probe for their own bottom as well as other sciences, or any philosophy, and it is altogether wholesome that

they should do so. The most serious source of error in the development of the earth-sciences, in my judgment, is our relative neglect to probe fundamental conceptions and to recognize the extent to which they influence the most common observations and interpretations. We need a method of thought that shall keep us alive to these basal considerations. To this end I believe it to be conducive to soundness of intellectual procedure to regard our whole system of interpretation as but an effort to develop a consistent system of workable hypotheses. I think we should do well to abandon all claims that we are reaching absolute truth, in the severest sense of that phrase, and content ourselves with the more modest effort to work out a system of interpretation which shall approve itself in practise under such tests as human powers can devise. Wherein lie

The Basal Criteria of Our Sciences?

I believe they lie essentially in *the working quality.* Whatever conforms thoroughly to the working requirements of nature probably corresponds essentially to the absolute truth, though it may be much short of the full truth. That may be accepted, for the time being, as true which duly approves itself under all tests, *as though it were true.* Whenever it seems to fail under test in any degree, confidence is to be withdrawn in equal degree, and a rectification of conceptions sought. This may well hold for all conceptions, however fundamental, whether they relate to the physical, the vital, or the mental phenomena which the earth presents. Let us entirely abandon the historic effort of the metaphysicians to build an inverted pyramid on an apex of axioms assumed to be incontestable truth, and let us rear our superstructure on the results of working trials applied as widely and as severely as possible. Let us seek our foundation in the broadest possible contact with phenomena. I hold that *the working test* when brought to bear in its fullest, most intimate and severest forms is *the supreme criterion* of that which should stand to us for truth. Our interpretative effort should, therefore, be to organize a complete set of working hypotheses for all phenomena, physical, vital and mental, so far as appropriate to our sphere of research. These should be at once the basis of our philosophy and of our science. These hypotheses should be constantly revised, extended and elaborated by all available means, and should be tested continually by every new relation which comes into view, until the crucial trials shall become as the sands of the sea for multitude and their severity shall have no bounds but the limits of human capacity. That which under this prolonged ordeal shall give the highest grounds of assurance may stand to us for science, that which shall rest more upon inference than upon the firmer modes of determination may stand to us for our philosophy, while that which lies beyond these, as something doubtless always will, may stand to us for the working material of the future.

UTILITARIAN SCIENCE.*

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IT falls to my lot to-day to discuss very briefly, in accordance with the program of this congress, some of the common features of utilitarian science, with a word as to present and future lines of investigation or instruction in some of those branches of the applications of knowledge which have been assigned to the present division.

Applied science can not be separated from pure science, for pure science may develop at any quarter the greatest and most unexpected economic values, while, on the other hand, the applications of knowledge must await the acquisition of knowledge, before any high achievement in any quarter can be reached. For these reasons, the classification adopted in the present congress, or any other classification of sciences into utilitarian science and other forms of science, must be illogical and misleading. Whatever is true is likely sometime to prove useful, and all error is likely to prove sometime disastrous. From the point of view of the development of the human mind, all truth is alike useful and all error is alike mischievous.

In point of development pure science must precede utilitarian science. Historically, this seems to be not true; for the beginnings of science in general, as alchemy, astrology and therapeutics, seem to have their origin in the desire for the practical results of knowledge. Men wanted to acquire gold, to save life, to forecast the future, not for knowledge's sake, but for the immediate results of success in these directions. But even here accurate knowledge must precede any success in its application, and accuracy of knowledge is all that we mean by pure science. Moreover, as through the ages the representatives of the philosophies of the day, the *a priori* explanations of the universe, were bitterly and personally hostile to all inductive conclusions based on the study of base matter, men of science were forced to disguise their work under a utilitarian cloak. This is more or less true even to this day, and the greatest need of utilitarian science is still, as a thousand years ago, that this cloak should be thrown off, and that a larger and stronger body of workers in pure science should be developed to give the advance in real knowledge on which the thousands of ingenious and noble applications to utilitarian ends must constantly depend.

It is a fundamental law of psychology that thought tends to pass over into action. Applied science is knowledge in action. It is the

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flower of that highest philanthropy of the ages by which not even thought exists for itself alone, but must find its end in the enlargement of human control over matter and force or the amelioration of the conditions of human life.

The development of all science has been a constant struggle, a struggle of fact against philosophy, of instant impressions against traditional interpretations, of truth against 'make-believe.' For men are prone to trust a theory rather than a fact; a fact is a single point of contact; a theory is a circle made of an infinite number of points, none of them, however, it may be, real points of contact.

The history of the progress of science is written in human psychology rather than in human records. It is the struggle of the few realities or present sense impressions against the multitude of past impressions, suggestions and explanations. I have elsewhere said that the one great discovery of the nineteenth century—forestalled many ages before—was that of the reality of external things. Men have learned to trust a present fact or group of facts, however contradictory its teachings, as apposed to tradition and philosophy. From this trust in the reality of the environment of matter and force, whatever these may be, the great fabric of modern science has been built up. Science is human experience of contact with environment tested, set in order, and expressed in terms of other human experience. Utilitarian science is that part of all this knowledge which we can use in our lives, in our business. What is pure science to one is applied science to another. The investigation of the laws of heredity may be strictly academic to us of the university, but they are utilitarian as related to the preservation of the nation or to the breeding of pigs. In the warfare of science the real in act and motive has been persistently substituted for the unreal. Men have slowly learned that the true glory of life lies in its wise conduct, in the daily act of love and helpfulness, not in the vagaries fostered by the priest or in the spasms of madness which are the culmination of war. To live here and now as a man should live constitutes the ethics of science, and this ideal has been in constant antithesis to the ethics of ecclesiasticism, of asceticism and of militarism.

The physical history of the progress of science has been a struggle of thinkers, observers and experimenters against the dominant forces of society. It has been a continuous battle, in which the weaker side in the long run is winner, having the strength of the earth behind. It has been incidentally a conflict of earth-born knowledge with opinions of men sanctioned by religion; of present fact with preestablished system, visibly a warfare between inductive thought and dogmatic theology.

The real struggle, as already indicated, lies deeper than this. It is the effort of the human mind to relate itself to realities in the midst of traditions and superstitions, to realize that Nature never contradicts herself, is always complex, but never mysterious. As a final result all

past systems of philosophy, perhaps all possible systems, have been thrown back into the realm of literature, of poetry, no longer controlling the life of action, which rests on fact.

This conflict of tendencies in the individual has become a conflict among individuals as each is governed by a dominant impulse. The cause of tradition becomes that of theology;—for men have always claimed a religious sanction for their own individual bit of cosmic philosophy. Just as each man in his secret heart, the center of his own universe, feels himself in some degree the subject of the favor of the mysterious unseen powers, so does society in all ages find a mystic or divine warrant for its own attitude towards life and action, whatever that may be.

The nervous system of man, inherited from that of the lower animals, may be regarded as primarily a means of making locomotion safe. The reflex action of the nerve center is the type of all mental processes. The sensorium, or central ganglion, receives impressions from the external world representing, in a way, various phases of reality. The brain has no source of knowledge other than sensation. All human knowledge comes through human experience. The brain, sitting in darkness, has the primary function of converting sensory impressions into impulses to action. To this end the motor nerves carry impulses outward to the muscles. The higher function of nerve action, which we call the intellect, as distinguished from simple reflex action and from instinct, is the choice among different responses to the stimulus of external realities. As conditions of life become more complex, the demands of external realities become more exacting. It is the function of the intellect to consider and of the mind to choose. The development of the mind causes and permits complexity in external relations. Safety in life depends on choosing the right response to external stimulus. Wrong choice leads to failure or to death.

From the demands of natural selection results the intense practicality of the mental processes. Our senses tell us the truth as to external nature, in so far as such phases of reality have been essential to the life of our ancestors. To a degree, they must have seen 'things as they really are,' else they should not have lived to continue the generation. Our own individual ancestors through all the ages have been creatures of adequate accuracy of sensation and of adequate power of thought. Were it not so they could not have coped with their environment. The sensations which their brains translated into action contained enough of absolute reality to make action safe. That our own ordinary sensations and our own inductions from them are truthful in their essentials, is proved by the fact that we have thus far safely trusted them. Science differs from common sense mainly in the perfection of its tools. That the instruments of precision used in science give us further phases of reality is shown by the fact that we can trust

our lives to them. We find it safer to do so than to trust our unaided senses.

While our senses tell us the truth as to familiar things, as rocks and trees, foods and shelter, friends and enemies, they do not tell us the whole truth: they go only so far as the demands of ancestral environment have forced them to go. Chemical composition our senses do not show. Objects too small to handle are too small to be seen. Bodies too distant to be reached are never correctly apprehended. Accuracy of sense decreases as the square of the distance increases. Sun and stars, clouds and sky, are in fact very different from what they seem to the senses.

In matters not vital to action, exactness of knowledge loses its importance. Any kind of belief may be safe, if it is not to be carried over into action. It is perfectly safe, in the ordinary affairs of life, for one who does not propose to act on his convictions to believe in witches and lucky stones, imps and elves, astral bodies and odic forces. It is quite as consistent with ordinary living to accept these as objective realities as it is to have the vague faith in microbes and molecules, mahatmas and protoplasm, protective tariffs and manifest destiny, which forms part of the mental outfit of the average American citizen to-day. Unless these conceptions are to be brought into terms of personal experience, unless in some degree we are to trust our lives to them, unless they are to be wrought into action, they are irrelevant to the conduct of life. As they are tested by action, the truth is separated from the falsehood, and the error involved in vague or silly ideas becomes manifest. As one comes to handle microbes, they become as real as bullets or oranges and as susceptible of being manipulated. But the astral body covers only ignorance and ghosts vanish before the electric light.

Memory pictures likewise arise to produce confusion in the mind. The record of past realities blends readily with the present. Men are gregarious creatures and their speech gives them the power to add to their own individual experiences the concepts and experiences of others. Suggestion and conventionality play a large part in the mental equipment of the individual man.

About the sense impressions formed in his own brain each man builds up his own subjective universe. Each accretion of knowledge must be cast more or less directly in terms of previous experience. By processes of suggestion and conventionality the ideas of the individual become assimilated to those of the multitude. Thus myths arise to account for phenomena not clearly within the ordinary experiences of life. And in all mythology the unknown is ascribed not to natural forces, but to the action of the powers that transcend nature, that lie outside the domain of the familiar and the real.

It has been plain to man in all ages that he is surrounded by forces stronger than himself, invisible and intangible, inscrutable in

their real nature, but terribly potent to produce results. He can not easily trace cause and effect in dealing with these forces; hence it is natural that he should doubt the existence of relations of cause and effect. As the human will seems capricious because the springs of volition are hidden from observation, so to the unknown will that limits our own we ascribe an infinite caprice. All races of men capable of abstract thought have believed in the existence of something outside themselves whose power is without human limitations. Through the imagination of poets the forces of nature become personified. The existence of power demands corresponding will. The power is infinitely greater than ours; the sources of its action inscrutable: hence man has conceived the unknown first cause as an infinite and unconditioned man. Anthropomorphism in some degree is inevitable, because each man must think in terms of his own experience. Into his own personal universe, all that he knows must come.

Recognition of the hidden but gigantic forces in nature leads men to fear and to worship them. To think of them either in fear or in worship is to give them human forms.

The social instincts of man tend to crystallize in institutions; even his common hopes and fears. An institution implies a division of labor. Hence, in each age and in each race men have been set apart as representatives of these hidden forces and devoted to their propitiation. These men are commissioned to speak in the name of each god that the people worship or each demon the people dread.

The existence of each cult of priests is bound up in the perpetuations of the mysteries and traditions assigned to their care. These traditions are linked with other traditions and with other mystic explanations of uncomprehended phenomena. While human theories of the sun, the stars, the clouds, of earthquakes, storms, comets and disease, have no direct relation to the feeling of worship, they can not be disentangled from it. The uncomprehended, the unfamiliar and the supernatural are one and the same in the untrained human mind; and one set of prejudices can not be dissociated from the others.

To the ideas acquired in youth we attach a sort of sacredness. To the course of action we follow we are prone to claim some kind of mystic sanction; and this mystic sanction applies not only to acts of virtue and devotion, but to the most unimportant rites and ceremonies; and in these we resent changes with the full force of such conservatism as we possess.

It is against limited and preconceived notions that the warfare of science has been directed. It is the struggle for the realities on the part of the individual man. Ignorance, prejudice and intolerance, in the long run, are one and the same thing. In some one line at least, every lofty mind throughout the ages has demanded objective reality. This struggle has been one between science and theology only because theological misconceptions were entangled with crude notions of other

sorts. In the experience of a single human life there is little to correct even the crudest of theological conceptions. From the supposed greater importance of religious opinions in determining the fate of men and nations, theological ideas have dominated all others throughout the ages; and in the nature of things, the great religious bodies have formed the stronghold of conservatism against which the separated bands of science have hurled themselves, seemingly, in vain.

But the real essence of conservatism lies not in theology. The whole conflict, as I have already said, is a struggle in the mind of man. From some phase of the warfare of science no individual is exempt. It exists in human psychology before it is wrought in human history. There is no better antidote to bigotry than the study of the growth of knowledge. There is no chapter in history more encouraging than that which treats of the growth of open mindedness. The study of this history leads religious men to avoid intolerance in the present, through a knowledge of the evils intolerance has wrought in the past. Men of science are spurred to more earnest work by the record that through the ages objective truth has been the final test of all theories and conceptions. All men will work more sanely and more effectively as they realize that no good to religion or science comes from 'wishing to please God with a lie.'

It is the mission of science to disclose—so far as it goes—the real nature of the universe. Its function is to eliminate, wherever it be found, the human equation. By methods of precision of thought and instruments of precision of observation and experiment, science seeks to make our knowledge of the small, the distant, the invisible, the mysterious as accurate, as practical, as our knowledge of common things. Moreover, it seeks to make our knowledge of common things accurate and precise, that this accuracy and precision may be translated into action. For the ultimate end of science as well as its initial impulse is the regulation of human conduct. Seeing true means thinking right. Right thinking means right action. Greater precision in action makes higher civilization possible. Lack of precision in action is the great cause of human misery; for misery is the inevitable result of wrong conduct. 'Still men and nations reap as they have strewn.'

A classic thought in the history of applied science is expressed in these words of Huxley: 'There can be no alleviation of the sufferings of man except in absolute veracity of thought and action, and a resolute facing of the world as it is.' 'The world as it is,' is the province of science. 'The God of the things as they are, is the God of the highest heaven.' And as to the sane man, the world as it is is glorious, beautiful, harmonious and divine, so will science, our tested and ordered knowledge of it, be the inspiration of art, poetry and religion.

Pure science and utilitarian science merge into each other at every point. They are one and the same thing. Every new truth can be

used to enlarge human power or to alleviate human suffering. There is no fact so remote as to have no possible bearing on human utility. Every new conception falls into the grasp of that higher philanthropy which rests on the comprehension of the truths of science. For science is the flower of human altruism. No worker in science can stand alone. None counts for much who tries to do so. He must enter into the work of others. He must fit his thought to theirs. He must stand on the shoulders of the past, and must crave the help of the future. The past has granted its assistance, to the fullest degree of the most perfect altruism. The future will not refuse; and, in return, whatever knowledge it can take for human uses, it will choose in untrammeled freedom. The sole line which sets off utilitarian science lies in the limitation of human strength and of human life. The single life must be given to a narrow field, to a single strand of truth, following it wherever it may lead. Some must teach, some must investigate, some must adapt to human uses. It is not often that these functions can be united in the same individual. It is not necessary that they should be united; for art is long, though life is short, and for the next thousand years science will be still in its infancy. We stand on the threshold of a new century; a century of science; a century whose discoveries of reality shall far outweigh those of all centuries which have preceded it; a century whose glories even the most conservative of scientific men dare not try to forecast. And this twentieth century is but one—the least, most likely—of the many centuries crowding to take their place in the line of human development. In each century we shall see a great widening of the horizon of human thought, a great increase of precision in each branch of human knowledge, a great improvement in the conditions of human life, as enlightenment and precision come to be controlling factors in human action.

In the remaining part of this address I shall discuss very briefly some salient features of practice, investigation and instruction in those sciences which in the scheme of classification of this congress have been assigned to this division. In this discussion I have received the invaluable aid of a large number of my colleagues in scientific work, and from their letters of kindly interest I have felt free to make some very interesting quotations. To all these gentlemen (a list too long to be given here) from whom I have received aid of this kind I offer a most grateful acknowledgment.

Engineering.

The development of the profession of engineering in America has been the most remarkable feature of our recent industrial as well as educational progress. In this branch of applied science our country has come to the very front, and this in a relatively short time. To this progress a number of distinct forces have contributed. One lies in the temperament of our people, their motive force, and their tendency to

apply knowledge to action. In practical life the American makes the most of all he knows. Favoring this is the absence of caste feeling. There is no prejudice in favor of the idle man. Only idlers take the members of the leisure class seriously. There is, again, no social discrimination against the engineer as compared with other learned professions. The best of our students become working engineers without loss of social prestige of any sort. Another reason is found in the great variety of industrial openings in America, and still another in the sudden growth of American colleges into universities, and universities in which both pure and applied sciences find a generous welcome. For this the Morrill Act, under which each state has developed a technical school, under federal aid, is largely responsible. In the change from the small college of thirty years ago, a weak copy of English models, to the American university of to-day, many elements have contributed. Among these is the current of enlightenment from Germany, and at the same time the influence of far-seeing leaders in education. Notable among these have been Tappan, Eliot, Agassiz and White. To widen the range of university instruction so as to meet all the intellectual, esthetic and industrial needs of the ablest men is the work of the modern university. To do this work is to give a great impetus to pure and to applied science.

Two classes of men come to the front in the development of engineering: the one, men of deep scientific knowledge, to whom advance of knowledge is due, the other the great constructive engineers; men who can work in the large and can manage great enterprises with scientific accuracy and practical success. Everywhere the tendency in training is away from mere craftsmanship and towards power of administration. The demands of the laboratory leave less and less time for the shop. "Two classes of students," says a correspondent, "should be encouraged in our universities: First, the man whose scientific attainments are such that he will be able to develop new and important processes, the details of which may be directly applied. This type of man is the scientific engineer. The other is the so-called practical man, who will not only actually carry on engineering work, but may be called on to manage large enterprises. If his temperament and ability are such as to give him a thorough command of business methods and details, while he is in addition a good engineer, he will find a field of great usefulness before him on leaving the university. The university should encourage young men to undertake the general executive work necessary to handling men and in the many details of large enterprises. The successful man of this character is necessarily a leader and the university should recognize that such a man can be of great influence in the world, if he is thoroughly and broadly educated."

"We need," says another correspondent, "men possessing a better general training than most of those now entering and leaving our engi-

neering schools. We need more thoroughly trained teachers of engineering, men who combine theoretical training with a wide and constantly increasing experience, men who can handle the factors of theory, practice and economics."

"Technical education," says another correspondent, "should look beyond the individual to the aggregate, and should aim to shape its activities so as to develop at the maximum number of points sympathetic and helpful relations with the industrial and engineering interests of the state. This means careful and steady effort towards the coordination of the activities of the technical school with the general condition of industry and engineering as regards its raw materials, its constructive and productive operations, its needs and demands with regard to personnel and its actual or potential trend of progress."

The coming era in engineering is less a period of discovery and invention than of application on a large scale of principles already known. Greater enterprises, higher potentialities, freer use of forces of nature, all these are in the line of engineering progress.

"The realm of physical science," says a correspondent, "has become to the practical man a highly improved agricultural land, whereas in earlier days it was a virgin country possessing great possibilities and exacting but little in the way of economic treatment."

In all forms of engineering, practise is changing from day to day; the principles remain fixed. In electricity, for example, the field of knowledge 'extends far beyond the direct limits or needs of electrical engineers.'

"The best criticism as to engineering education came formerly almost entirely from professors of science and engineering. To-day the greatest and most wholesome source of such criticism comes from those engaged in practical affairs. We have begun a regime wherein coordinated theory and practise will enter into the engineering training of young men to a far greater and more profitable extent than ever before."

"The marvelous results in the industrial world of to-day," says a correspondent, "are due largely to the spirit of 'usefulness, activity, and cooperation' that exists in each community of interests and which actuates men employing the means which applied science has so bountifully accorded. I know of no greater need of engineering education in our country to-day than that its conduct in each institution should be characterized by the same spirit of usefulness, activity and cooperation."

In mining, as in other departments of engineering, we find in the schools the same growing appreciation of the value of training at once broad, thorough and practical, and the same preference for the university-trained engineer in preference to the untrained craftsman.

The head of a great mining firm in London writes me that 'for our business, what we desire are young men of good natural qualifica-

tions, thoroughly trained theoretically without any so-called practical knowledge unless this knowledge has been gained by employment in actual works.'

On the pay-roll of this English firm I find that five men receive salaries of more than $20,000. All these are graduates of technical departments of American universities. Seventeen receive from $6,000 to $20,000. Nine of these were trained in American universities, one in Australia and two in England, while five have risen from the ranks.

In the lower positions, most have been trained in Australia, a few in England, while in positions bearing a salary of less than $2,500, most have risen from the ranks.

" Given men of equal qualifications," says the director of this firm, " the man of technical training is bound to rise to the higher position because of his greater value to his employer. As a rule, also, men who have been technically trained are, by virtue of their education, men who are endowed with a professional feeling which does not to the same extent exist among those men who have risen from the rank and file. They are therefore more trustworthy and especially in mining work, where premium for dishonesty exists, for this qualification alone they are bound to have precedence. We do not by any means wish to disparage the qualifications of many men who have risen from the ranks to eminent positions, but our opinion may be concentrated in the statement that even these men would be better men had they received a thorough technical training."

The progress of chemical engineering is parallel with that in other departments of technology. Yet the appreciation of the value of theoretical training is somewhat less marked, and in this regard our manufacturers seem distinctly behind those of Germany.

" The development of chemical industries in the past history of the United States," says a correspondent, " was seriously delayed by the usually superficial and narrow training of the chemist in the colleges. Thus managers and proprietors came to undervalue the importance of chemical knowledge. The greatest need at present in the development of chemical industries is an adequate supply of chemists of thorough training to teach manufacturers the importance in their business of adequate chemical knowledge. Epoch-making advances in chemical industry will spring from the brain of great chemists, and to ensure the production of a few of these, the country must expect to seed lavishly and to fertilize generously the soil from which they spring. Germany has learned the lesson well: other nations can not long delay."

In the vast range of the applications of science to agriculture, the same general statements hold good. There is, however, no such general appreciation of the value of training as appears in relation to the various branches of training, and the men of scientific education are mostly absorbed in the many ramifications of the Department of Agriculture and in the state agricultural colleges and experiment stations.

There are few illustrations of the power of national cooperation more striking than those shown in the achievements of the Department of Agriculture. I have no time to touch on the varied branches of agricultural research, the study of the chemistry of foods and soils, the practise of irrigation, the fight against adulterations, the fight against noxious insects, and all the other channels of agricultural art and practise. I can only commend the skill and the zeal with which all these lines of effort have been followed.

The art of agriculture is the application of all the sciences. Yet 'agricultural education,' writes a correspondent, 'has not yet reached the dignity of other forms of technical education.'

"The endowment of the science of agricultural research in the United States is greater than in any other country. The chief fault to be found is in striving too rapidly for practical applications and in not giving time enough for the fundamental research on which these applications must rest. The proportion of applied agricultural science in agriculture is too great in this country. While we do not need fewer workers in applied agricultural science, we do need more workers who would devote themselves to fundamental research."

Two branches of applied science not specifically noticed in our scheme of classification seem to me to demand a word of notice. One is selective breeding of plants and animals; the other, the artificial hatching of fishes. By the crossing of animals or plants not closely related, a great range of variety appears in the progeny. Some of these may have one or more of the desirable qualities of either parent. By selection of those possessing such qualities a new race may be formed in a few generations. The practical value of the results of such experiments can not be over-estimated. Although by no means a modern process, the art of selective breeding is still in its infancy. Its practise promises to take a leading place among the economically valuable applications of science. At the same time, the formation of species of organisms under the hand of man throws constant floods of light on the great questions of heredity, variation and selection in nature, the problem of the origin of species.

In this connection I may refer to artificial hatching and acclimatization of fishes, the work of the United States Bureau of Fisheries and of the fish commissions of the different states. There are many species of fish, notably those of the salmon family, in which the eggs can be taken and fertilized by artificial processes. These eggs can be hatched in protected waters so that the young will escape many of the vicissitudes of the brook and river, and a thousand young fishes can be sent forth where only a dozen grew before.

Medicine.

In the vast field of medicine I can only indicate in a few words cer-

tain salient features of medical research, of medical practise, and of medical instruction in America.

In matters of research, the most fruitful line of investigation has been along the line of the mechanism of immunity from contagious diseases. To know the nature of microorganisms and their effect on the tissues is to furnish the means of fighting them. 'The first place in experimental medicine to-day,' says Dr. W. H. Welch, 'is occupied by the problem of immunity.' That medicine is becoming a scientific profession and not a trade is the basis of the growing interest of our physicians in scientific problems, and this again leads to increased success in dealing with matters of health and disease. The discovery of the part played by mosquitoes in the dissemination of malaria, yellow fever, dengue, elephantiasis and other diseases caused by microorganisms marks an epoch in the study of these diseases. The conquest of diphtheria is another of the features of advance in modern medicine, and another is shown in the great development of surgical skill characteristic of American medical science. But the discoveries of the last decades have been rarely startling or epoch-making. They have rather tended to fill the gaps in our knowledge, and there remain many more gaps to fill before medical practise can reach the highest point of adequacy. The great need of the profession is still in the direction of research, and research of the character which takes the whole life and energy of the ablest men demands money for its maintenance. We need no more medical colleges for the teaching of the elements. We need schools or laboratories of research for the training of the masters.

In the development of medicine there has been a steady movement away from universal systems and *a priori* principles, on the one hand, and, on the other hand, from blind empiricism, with the giving of drugs with sole reference to their apparent results. The applications of science—all sciences which deal with life, with force and with chemical composition—must enter into the basis of medicine. Hence the insistent demand for better preliminary training before entering on the study of medicine. "Only the genius of the first order," says a correspondent, "can get on without proper schooling in his youth. What our medical investigators in this country most need is a thorough grounding in the sciences, especially physics and chemistry."

The instruction in medicine, a few years ago almost a farce in America, has steadily grown more serious. Laboratory work and clinical experience have taken the place of lectures, the courses have been lengthened, higher preparation for entrance has been exacted, though in almost all our schools these requirements are still far too low, and a more active and original type of teacher has been in demand. Even yet, so far as medical instruction is concerned, the hopeful sign is to be found in progress rather than in achievement. A college course, having as its major subjects the sciences fundamental to

medicine, is not too much to exact of a student who aspires to be a physician worthy of our times and of the degree of our universities. First hand knowledge of real things should be the key-note of all scientific instruction. "Far more effort is now made," writes a correspondent, "in both the preparatory and the clinical branches to give the student a first hand knowledge of the subject. This tendency has still a long way to travel before it is in danger of being overdone. The practical result of this tendency is that the cost of education per student is greatly increased and the profits of purely commercial schools are thereby threatened. This forms, doubtless, the main source of the objection made by the weaker and less worthy schools to better methods of instruction. We need well endowed schools of medicine that may carry on their work unhampered by the necessities of a commercial venture. Medical schools now exist in great numbers,—many of them can not keep up with modern requirements, and necessarily their salvation lies in antagonizing everything in the nature of more ample and more expensive training."

Another correspondent writes, emphasizing the value of biologic studies: "The final comprehension of bodily activity in health and disease depends on knowledge of living things from ovum to birth, from birth to maturity, and from maturity to old age and death. Anything less than such fundamental knowledge requires constant guessing to fill up the gaps, and guesses are nearly always wrong."

In many regards, even our best schools of medicine seem to show serious deficiencies. The teaching of anatomy is still one of the most costly, as well as least satisfactory, of our lines of work. A correspondent calls attention to the fact that in making anatomy 'practical' in our medical schools 'we expended last year $750,000 in the United States, twice the amount expended in Germany, with as a result neither practical anatomy nor scientific achievement.' "Anatomy," he continues, "should be made distinctly a university department, on a basis similar to that of physics and chemistry. Unfortunately, university presidents still stand much in the way of the development of anatomy, for many of them seem to think that almost any one who wears the gown is good enough to become a professor of anatomy. Repeatedly have I witnessed the appointment of a know-nothing when a recognized young man might have been had for half the money." Our forces are dissipated, the fear of things scientific has destroyed even the practical in this noble old mother science which is still giving birth to new sciences and to brilliant discoveries.

Among other matters too much neglected are personal hygiene, a matter to which the physician of the past has been notoriously and joyously indifferent. Especially is this true as regards the hygiene of exercise and the misuse of nerve-affecting drugs.

Public sanitation as well deserves more attention. "The demand for adequately trained officers of public health is not what it should be,

and our public service as a whole is far below that of European countries. Both public opinion and university authorities are responsible for this condition."

The hygiene of childhood, in which line great advances are made, is still not adequately represented in most of our medical colleges, and the study of psychiatry and nervous disturbances in general is not sufficiently lifted from the realm of quackery. "Not only," says a correspondent, "should psychiatry be taught in every medical school, but it should be taught from a clinical standpoint. Every city in which there are medical schools should have a psychopathic hospital for the reception of all cases of alleged insanity and for their study, treatment and cure. Such a hospital should contain, also, a laboratory for the study of normal and of pathological psychology. I am convinced that progress in normal psychology will be made chiefly through the study of abnormal conditions, just as physiology has profited so enormously through the work of the pathologist."

A word should be said for veterinary medicine and its achievements of enormous economic value in the control of the contagious diseases of animals. The recent achievements of vaccination against the southern cattle fever and against tuberculosis, the eradication of the foot and mouth disease among other matters, have demanded the highest scientific knowledge and the greatest skill in its practical application.

Unfortunately, veterinary science lacks in this country adequate facilities for research and instruction. "Practically," says a correspondent, "the veterinary sciences in the United States are leading a parasitic existence. We are dependent almost wholly upon the results of investigation and teaching of European countries, notably Germany and Denmark. The value of the live-stock industry here is so tremendous that almost every state in the Union should have a well-equipped veterinary school supported by public funds. There is but one veterinary school in the United States that has anything like adequate support." That this is true shows that our farmers and stock-raisers are very far from having an adequate idea of one of the most important of their economic needs.

Economics.

We may justify the inclusion of economics among the utilitarian sciences on grounds which would equally include the sciences of ethics and hygiene. It is extremely wise as well as financially profitable to take care of one's health, and still more so to take thought of one's conduct. The science of economics in some degree touches the ethics of nations and the 'wealth of nations,' a large factor in the happiness of the individuals contained within them, depends on the nation's attitude towards economic truths. Another justification of this inclusion is found in the growing tendency in our country to call on professional

economists to direct national operations. On the other hand, our economists themselves are becoming more and more worthy of such trusts. The inductive study of their science brings them into closer contact with men and with enterprises. By this means they become students of administration as well as of economics. They realize the value of individual effort as well as the limitations which bound all sorts of executive work, in a republic. "Only a few years ago," writes a correspondent, "the teachers of economics were far more generally unfavorable critics of government work which interested them. They have become more and more disposed to cooperate at the beginning rather than to condemn at the end. Just as economics has taken a more kindly and hospitable attitude towards politics, so similarly has it towards business, as illustrated in the rapid rise of courses in commerce." The demand for trained economists in public affairs is 'compelling the teachers of economics more and more to seek contact with the men who are grappling face to face with economic problems.'

The relation of economic theory to administration is a subject on which there is much diversity of opinion. It is claimed by able authority that "Economic science, by becoming ultra-theoretical, has come into far closer touch with practical life than it ever attained before. Laws, the statement of which seems like a refinement of theory, determine the kind of legislation required on the most practical of subjects." On another hand, it is claimed by high authority that our country must have its own political economy. "The generalizations arising solely from the uniformity of human nature are so few that they can not constitute a science. The classical or orthodox Political Economy of England was conditioned from start to finish by the political problems it had to face. We are only beginning to acquire our national independence."

Still another view is that "all that has been achieved in the field of economics that is of any value, has been the result of logical analysis applied to the phenomena and experiences of every-day industrial life. The stages of past development can be determined and interpreted only in the light of this analysis. The lesson which the historical economist has never learned, is the importance of that principle, which lies at the bottom of the whole modern theory of evolution, and which was made use of by Lyell and Darwin, namely, the principle that historical changes of the past are to be accounted for by the long continued action of causes which are at this present moment in operation and can be observed and measured at the present day." "This," says my correspondent, "needs saying and resaying, until it is burned into the minds of all students of economics."

The recent progress of economics in America has lain in part in the development of economic theory by critical and by constructive methods. An important reason for welcoming the exact and critical study of economic theory is this: In the promulgation of imaginary

economic principles the social and political charlatan finds his choice field of operation, just as the medical charlatan deals with some universal law of disease and its universal cure. The progress of science in every field discredits these universal principles with their mystical panaceas. There is all the more reason why in politics, as in medicine, those generalizations which deal with necessary laws or actually observed sequence of events should be critically and constructively studied.

In general, however, the progress of economics has followed the same lines as progress in other sciences, through a 'minute investigation and the application of principles already discovered or outlined by painstaking inquiry as to facts.' This method of work has been especially fruitful in the study of monetary problems, of finance, taxation and insurance, in the study of labor problems and conditions, in the study of commerce and in the study of crime and pauperism. In its development economics is, however, many years behind the natural sciences, a condition due to reliance on metaphysical methods and to the inherent difficulty in the use of any other.

"Economics," says a correspondent, "has been less successful than the material sciences in getting rid of the apparatus of metaphysical presumptions. The economist is still too eager to formulate laws that shall disclose the ultimate spiritual meaning of things instead of trying to explain how these things came to pass. He has profited in small degree by those lessons which the progressive evolutionary sciences have driven home in the past, in the methods of thinking of workers in other fields. Our science is still sadly behind the times in its way of handling its subject matter. The greatest and most important work of economic investigations is to make students see things as they are, to fit young men for the more highly organized business new conditions are ushering in, and give a better appreciation of the problems of government and a better training for participation in them."

Says another correspondent: "Training in research is in fact essential to every technical man. The young technologist will be confronted by new problems not covered by anything in literature or in his past experience. Training in research is training in the art of solving unsolved problems, and the practical man who has had discipline of that kind has a great advantage over his more conventional competitors. The Germans recognize this principle, and behold their marvelous industrial growth. The student in every department of science should be taught to think as well as to do."

The time must come when a man who has no training and no experience in research will not be called educated, whatever may be the range of his erudition. To unfold the secret of power is the true purpose of education.

THE EVOLUTION OF THE SCIENTIFIC INVESTIGATOR.*

By Professor SIMON NEWCOMB, U. S. N. (retired),

WASHINGTON, D. C.

AMONG the tendencies characteristic of the science of our day is one toward laying greater stress on questions of the beginning of things, and regarding a knowledge of the laws of development of any object of study as necessary to its complete understanding in the form in which we find it. It may be conceded that the principle here involved is as applicable in the broadest field of thought as in a special research into the properties of the minutest organism. It, therefore, seems meet that the comprehensive survey of the realm of knowledge on which we are about to enter should begin by seeking to bring to light those agencies which have brought about the remarkable development of that realm to which the world of to-day bears witness. The principle in question is recognized in the plan of our proceedings by providing for each great department of knowledge a review of its progress during the century that has elapsed since the great event which the scene around us is intended to commemorate. But such reviews do not make up that general survey of science at large which is necessary to the development of our theme, and which must include the action of causes that had their origin long before our time. The movement which culminated in making the nineteenth century ever memorable in history is the outcome of a long series of causes, acting through many centuries, which are worthy of being brought into especial prominence on such an occasion as this. In setting them forth we should avoid laying stress on those visible manifestations which, striking the eye of every beholder, are in no danger of being overlooked, and search rather for those agencies whose activities underlie the whole visible scene, but which are liable to be blotted out of sight by the very brilliancy of the results to which they have given rise. It is easy to draw attention to the wonderful qualities of the oak; but, from that very fact, it may be needful to point out that the real wonder lies concealed in the acorn from which it grew.

Our inquiry into the logical order of the causes which have made our civilization what it is to-day will be facilitated by bringing to mind certain elementary considerations—ideas so familiar that setting them forth may seem like citing a body of truisms—and yet so frequently

* Opening and concluding parts of the address of the president of the International Congress of Arts and Science, at the St. Louis Exposition, September 19, 1904.

overlooked not only individually, but in their relation to each other, that the conclusion to which they lead may be lost to sight. One of these propositions is that psychical rather than material causes are those which we should regard as fundamental in directing the development of the social organism. The human intellect is the really active agent in every branch of endeavor—the *primum mobile* of civilization —and all those material manifestations to which our attention is so often directed are to be regarded as secondary to this first agency. If it be true that 'in the world is nothing great but man; in man is nothing great but mind,' then should the keynote of our discourse be the recognition at every step of this first and greatest of powers.

Another well-known fact is that those applications of the forces of nature to the promotion of human welfare which have made our age what it is are of such comparatively recent origin that we need go back only a single century to antedate their most important features, and scarcely more than four centuries to find their beginning. It follows that the subject of our inquiry should be the commencement, not many centuries ago, of a certain new form of intellectual activity.

Having gained this point of view our next inquiry will be into the nature of that activity, and its relation to the stages of progress which preceded and followed its beginning. The superficial observer, who sees the oak but forgets the acorn, might tell us that the special qualities which have produced such great results are expert scientific knowledge and rare ingenuity, directed to the application of the powers of steam and electricity. From this point of view the great inventors and the great captains of industry were the first agents in bringing about the modern era. But the more careful inquirer will see that the work of these men was possible only through a knowledge of laws of nature which had been gained by men whose work took precedence of theirs in logical order, and that success in invention has been measured by completeness in such knowledge. While giving all due honor to the great inventors, let us remember that the first place is that of the great investigators whose forceful intellects opened the way to secrets previously hidden from men. Let it be an honor and not a reproach to these men that they were not actuated by the love of gain, and did not keep utilitarian ends in view in the pursuit of their researches. If it seems that in neglecting such ends they were leaving undone the most important part of their work, let us remember that nature turns a forbidding face to those who pay her court with the hope of gain, and is responsive only to those suitors whose love for her is pure and undefiled. Not only is the special genius required in the investigator not that generally best adapted to applying the discoveries which he makes, but the result of his having sordid ends in view would be to narrow the field of his efforts, and exercise a depressing effect upon his activities. It is impossible to know what application knowledge

may have until after it is acquired, and the seeker after purely useful knowledge will fail to acquire any real knowledge whatever.

We have here the explanation of the well-known fact that the functions of the investigator of the laws of nature, and of the inventor who applies these laws to utilitarian purposes are rarely united in the same person. If the one conspicuous exception which the past century presents to this rule is not unique, we should probably have to go back to Watt to find another. The true man of science of to-day and of all past time has no such expression in his vocabulary as useful knowledge. His domain is the whole of nature, and were he to attempt its division into the useful and the useless, he would drop from his high estate.

It is, therefore, clear that the primary agent in the movement which has elevated man to the masterful position he now occupies is the scientific investigator. He it is whose work has deprived plague and pestilence of their terrors, alleviated human suffering, girdled the earth with the electric wire, bound the continent with the iron way, and made neighbors of the most distant nations. As the first agent which has made possible this meeting of his representatives, let his evolution be this day our worthy theme.

It has been said that the scientific investigator is a new species of the human race. If this designation is applicable to a class defined only by its functions, then it is eminently appropriate. But the biologist may object to it on the ground that a species, or even a variety, is the product of heredity, and propagates only or mainly its own kind. The evolutionist may join hands with him on the ground that only new faculties, not new modes of activity, are to be regarded as products of evolution, but let us not stop to dispute about words. We have no need of the term 'species' in our present course of thought; but to deny the term evolution to the genesis of previously non-existent forms of intellectual activity is to narrow our conception of the course of nature, and draw a line of demarkation where no tangible boundary exists.

I am the more ready to invite your attention to the evolution of the scientific investigator, not only because the subject is closely correlated with human evolution in general, but because it is one branch of evolution which seems to me not to have received due prominence in discussions of the subject.

* * * * * *

There is an increasing recognition of methods of research and of deduction which are common to large branches or to the whole of science. We are more and more recognizing the principle that progress in knowledge implies its reduction to a more exact form, and the expression of its ideas in language more or less mathematical. The problem before the organizers of this congress was, therefore, to bring the sciences together, and seek for the unity which we believe underlies

their infinite diversity. The assembling of such a body as now fills this hall was scarcely possible in any preceding generation, and is made possible now only through the agency of science itself. It differs from all preceding international meetings by the universality of its scope, which aims to include the whole of knowledge. It is also unique in that none but leaders have been sought out as members. It is unique in that so many lands have delegated their choicest intellects to carry on its work. They come from the country to which our republic is indebted for a third of its territory, including the ground on which we stand; from the land which has taught us that the most scholarly devotion to the languages and learning of the cloistered past is compatible with leadership in the practicable application of modern science to the arts of life; from the island whose language and literature have found a new field and a vigorous growth in this region; from the last seat of the holy Roman Empire; from the country which, boasting of the only monarch that ever made an astronomical observation at the Greenwich Observatory, has enthroned science in one of the highest places in its government; from the peninsula so learned that we have invited one of its scholars to come here and teach us our own language; from the land which gave birth to Leonardo, Galileo, Torricelli, Columbus, Volta—what an array of immortal names!—from the little republic of glorious history which, breeding men rugged as its eternal snow-peaks, has yet been the seat of scientific investigation since the day of the Bernoullis; from the land whose heroic dwellers did not hesitate to use the ocean itself to protect it against invaders, and which now makes us marvel at the amount of erudition compressed within its little area; from the nation of the farthest east, which, by half a century of unequaled progress in the arts of life, has made an important contribution to evolutionary science through demonstrating the falsity of the theory that the most ancient races are doomed to be left in the rear of the advancing age—in a word, from every great center of intellectual activity on the globe I see before me eminent representatives of that world-advance which we have come to celebrate.

Gentlemen and scholars all! You do not visit our shores to find great collections in which long centuries of humanity have given expression on canvas and in marble to their hopes, fears and aspirations. Nor do you expect institutions and buildings hoary with age. But as you feel the vigor latent in the fresh air of these expansive prairies, which has collected the products of human genius by which we are here surrounded and, I may add, brought us together—as you study the institutions which we have founded for the benefit not only of our own people but of humanity at large; as you meet the men who, in the short space of one century, have transformed this valley from a savage wilderness into what it is to-day—then may you find compensation for the want of a past like yours by seeing with prophetic

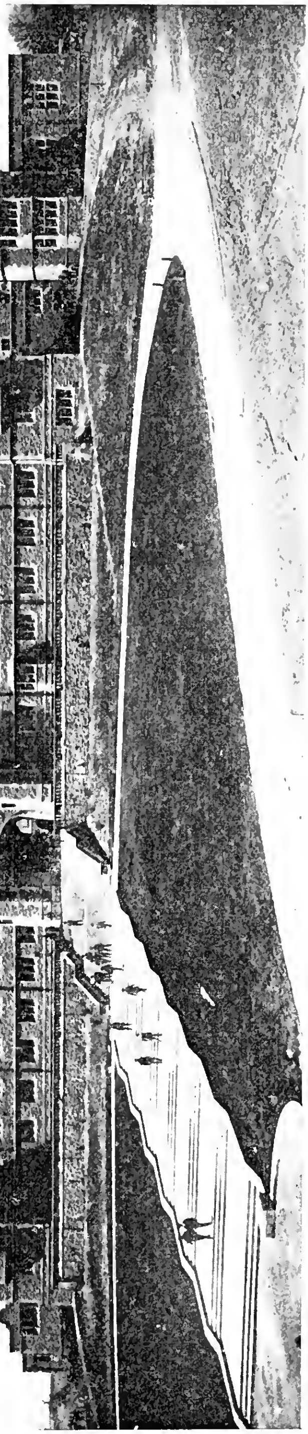
eye a future world power of which this region shall be the seat. If such is to be the outcome of the institutions which we are now building up, then may your present visit be a blessing both to your posterity and ours, by making that power one for good to all mankind. Your deliberation will help to demonstrate to us and to the world at large that the reign of law must supplant that of brute force in the relations of the nations, just as it has supplanted it in the relations of individuals. You will help to show that the war which science is now waging against the sources of disease, pain and misery offers an even nobler field for the exercise of heroic qualities than can that of battle. We hope that when, after your all too fleeting sojourn in our midst, you return to your own shores, you will long feel the influence of the new air you have breathed in an infusion of increased vigor in pursuing your varied labors. And if a new impetus is thus given to the great intellectual movement of the past century, resulting not only in promoting the unification of knowledge, but in widening its field through new combinations of effort on the part of its votaries, the projectors, organizers and supporters of this Congress of Arts and Science will be justified of their labors.

THE PROGRESS OF SCIENCE.

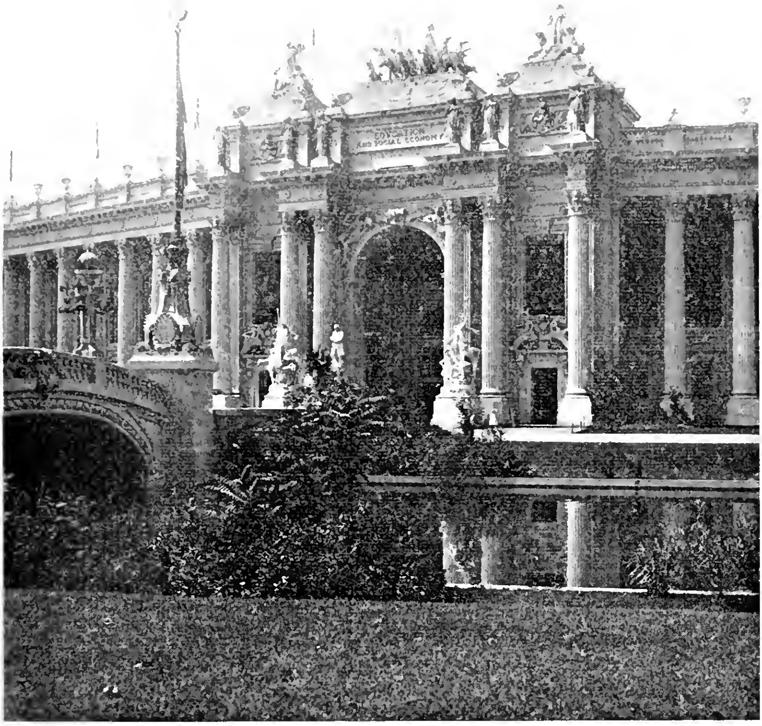
THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCE.

This number of The Popular Science Monthly is given to the St. Louis Congress of Arts and Science, which is certainly an event in the history of science deserving special commemoration. Never before in the world have there come together a group of scholars whose average performanee is so great, and it is a matter for legimate national pride that this assemblage should have gathered in the United States. The objects of the congress were described by Professor Newcomb, the president, in the September issue of the *Monthly*, and there is given above

Festival Hall, in which the Opening Exercises of the International Congress of Arts and Science were held.



Administration Building, being part of Washington University, which was the Headquarters of the International Congress of Arts and Science.



Palace of Education and Social Economy.

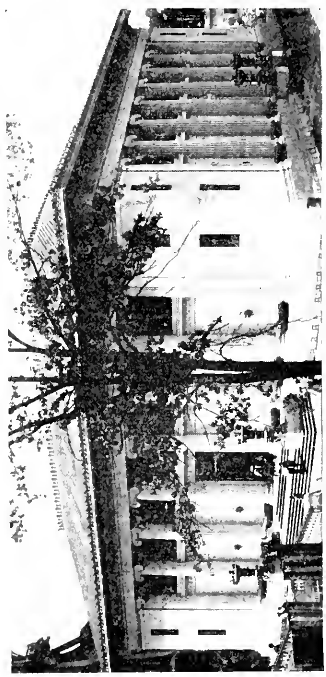
an appreciation of its work by Mr. Wm. Harper Davis, of Lehigh University, one of the secretaries. The articles following are addresses given at the congress, which have not been published elsewhere.

International congresses have gradually come to be a part of international expositions. At Paris over a hundred congresses were held, extending through the summer, and the sessions and the subsequent publication of the proceedings form an important chapter in the history of modern science. When the managers of the St. Louis exposition decided to make international congresses a part of their scheme, they appointed a representative administrative board, with President Nicholas Murray Butler, of Columbia University, as chairman. This board adopted the plan proposed by Professor Münsterberg, of Harvard University, to hold one congress of the arts and sciences which should attempt to promote and demonstrate the unity of science. Professor Newcomb was appointed president, and Professors Münsterberg and Small, vice-presidents, and at the same time acted as a committee of organization.

All this is, however, told in Mr. Davis's article. After giving the praise and appreciation that is due, it may be well to call atention to some of the lessons of the congress. It was a fine idea to have the whole range of modern civilization represented in a great international gathering of the leaders in all departments of the sci-

Palace of Agriculture, which covers Twenty Acres.

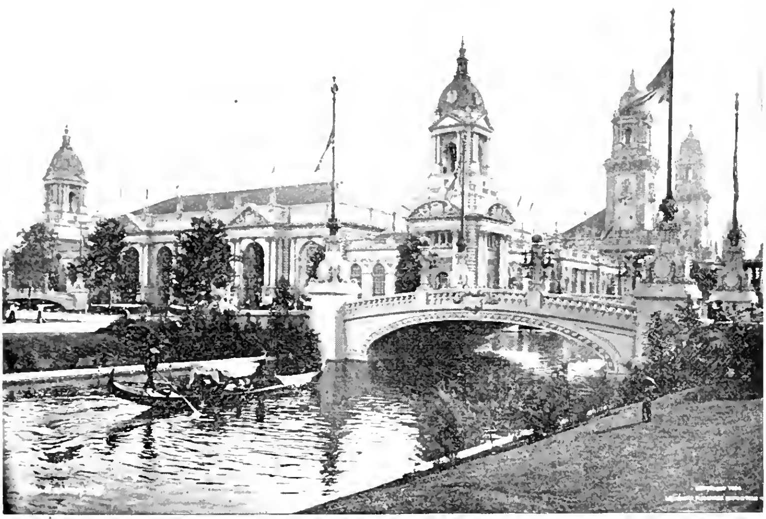
Indian School.



Fisheries Building.

ences and the arts. The attempt to unify knowledge on the lines of a particular philosophical system must naturally fail. No one supposes that a conference at the Hague will give the world enduring peace, or that a congress at St. Louis will unify the sciences. Indeed there are those who hold that science will be unified only when it is dead, and that any scheme of unification is more useful in promoting controversy than in prescribing a final solution. It is probable that very few of the speakers were even aware of Professor Münsterberg's plan or had read his article in the *Atlantic Monthly*. The addresses that dealt with some special problem to which the author had contributed were the best. The divisions intended to unify the sciences were superfluous. As a matter of fact it is more feasible and more profitable to unify men of science than to perfect a logical scheme of the sciences, and in this direction the congress was only moderately successful.

Incidentally much was indeed accomplished, the main result being the bringing of a hundred leading foreign scholars to this country. Not only at the congress, but in their visits to other places, they have taught us many things, and it may be hoped have learned some things from us. The two hundred thousand dollars expended is a considerable sum, and possibly still more might have been accomplished with it. It is doubtful whether the limitation of the meeting to a single week represents any advance over the series of congresses of the Paris exposition. If the dormitories of Washingeon University, with a proper dining-room and rooms for sessions and social intercourse, had been placed at the disposal of our national societies, and they had held a series of meetings during the summer, with perhaps one week for general addresses by a score of invited scholars, the results would probably have been better.



Palace of Machinery.

As it was the week of the congress was overcrowded. Each of the some three hundred speakers addressed an

PALACE OF ELECTRICITY.

audience which probably averaged about fifty, consisting in part of specialists and in part of chance visitors. It was but seldom that students of one science listened to speakers in another, and the opportunities to become personally acquainted were inadequate. Officers of the army of science were paid to be present, but the rank and file of American workers were not there. And this was largely the fault of defective organization. We have, apart from the national scientific societies and local academies, at least four institutions which should have worked in harmony with the congress—the American Association for the Advancement of Science, the National Academy of Sciences, the Smithsonian Institution and the Carnegie Institution. But the cooperation of none of these bodies was secured, the head of none of them was present at St. Louis. They even worked at cross purposes, the American Association having met at St. Louis last Christmas and the National Academy having met at Chicago in November. An attempt to unify science which made no use of existing organizations was seriously at fault. The management also failed to bring science and scholarship into con-

tact with the wider public, the congress passing almost unnoticed, except by those immediately concerned.

But it may seem ungracious to call attention to what was not done when so much was in fact accomplished. The congress was worth many fold the efforts and the money that it cost. For the first time in the history of the world the attempt was made to bring together the leaders in all departments of science, scholarship and the arts. The large plan will ultimately emerge from the mass of details and will be a landmark in the history of civilization.

PALACE OF MINES AND METALLURGY.

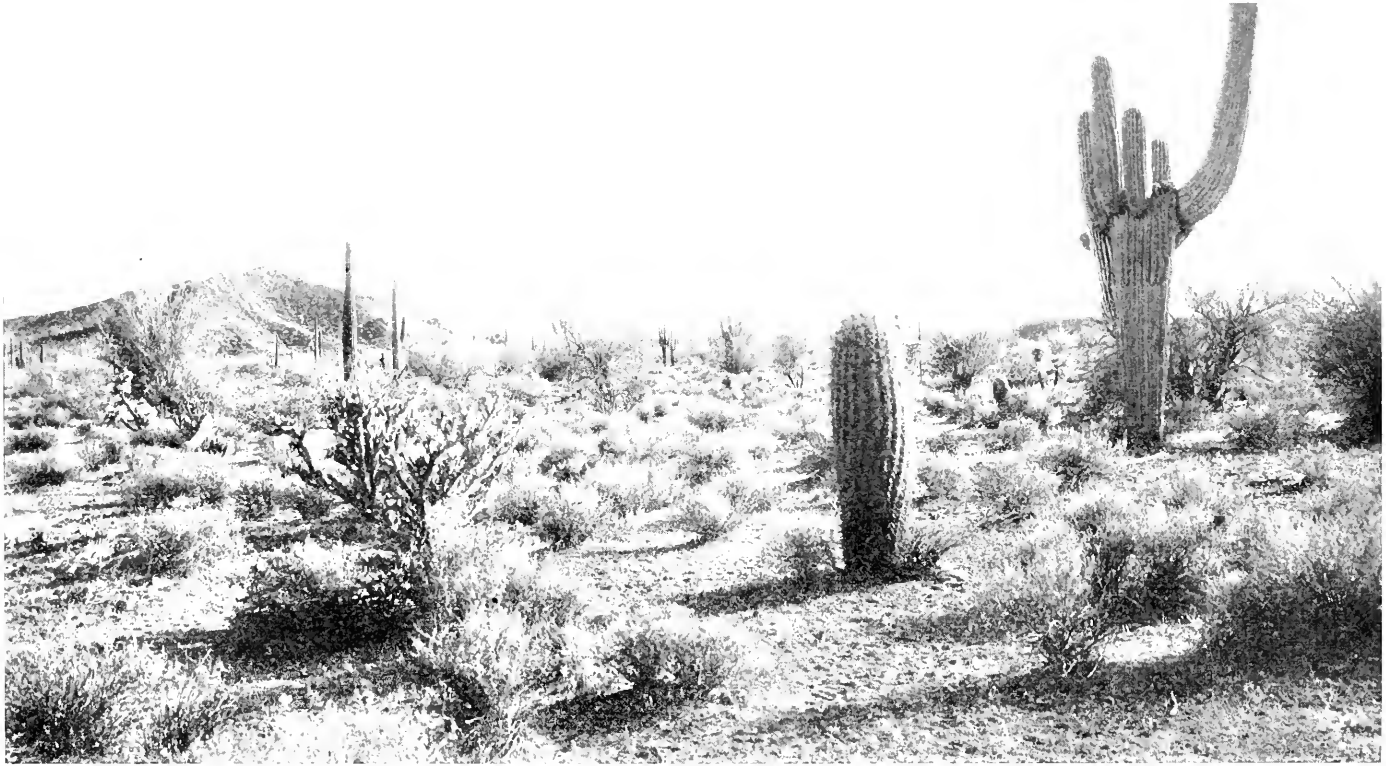
THE LOUISIANA PURCHASE EXPOSITION.

An international exposition offers certain advantages and certain drawbacks as a place of meeting for an international congress. The drawbacks—both physical and mental—are sufficiently obvious. They are perhaps given more weight than they deserve, and thus a new obstacle is set up. With a comparatively small change in the conditions that have ordinarily prevailed, an exposition and a congress should help each other. They have in many ways the same ends in view. As civilization advances science and the arts become an increasing part of life. The St. Louis exposition, all the way from the Pike to the International Congress of Arts and Science, overlaps continually with the objects and the field of this magazine. It would be satisfactory if we could give an adequate appreciation and criticism of the exposition, but this does not appear to be feasible. It may, however, be worth the while in a number of the Monthly devoted to the International Congress to give some illustrations showing its material setting, and to devote a few words to the exposition itself.

The magnitude of the exposition, its hundreds of buildings, measured by the acre, and the tens of millions of dollars that it cost have been duly advertised; and allowance is made by sensible people for crudeness, flimsiness and heterogeneity. A certain architectural unity has been given to the whole scheme by the fan-like radiating avenues or plazas which converge towards the central festival hall. At night, under the electric illumination, the effects are marvelous and beautiful. It can scarcely be claimed, however, that any significant advance has been made beyond the Chicago exposition. It seems that the limits of magnitude and universality have been reached, and that subsequent international expositions, should they occur, must aim to surpass their predecessors in completeness in some particular direction.

In the classification of the St. Louis Exposition education was given the central place, and the fact that the new buildings of Washingeon University were occupied also emphasized higher education. Germany made a fine educational exhibit, and an Indian school and other schools were shown in operation. It would have been well if the buildings of Washington University could have been used to show a national or international university in operation with the speakers of the International Congress as the teachers; but this would doubtless be asking too much. Anthropology, directly and indirectly, should occupy a prominent place in an international exposition. At St. Louis the Philippine exhibit was timely and well arranged, with its native villages and the thousand representatives of the different peoples.

The progress of the applied sciences since the Chicago exposition is doubtless the most notable feature of the period, and this was adequately represented at St. Louis. The names of the buildings—agriculture, machinery, electricity, mines and metallurgy, etc.—make it clear that an exposition is practically an exhibit of applied science. The advances in America during this period have probably been unsurpassed, but the exhibits of Germany and Japan show that they are not unrivaled.



Typical Arizona Desert Scene without Irrigation.

THE
POPULAR SCIENCE
MONTHLY.

DECEMBER, 1904.

THE RECLAMATION SERVICE.

By F. H. NEWELL,
CHIEF ENGINEER, RECLAMATION SERVICE, U. S. GEOLOGICAL SURVEY.

A RECENT and notable addition to the work of the government in applied science is the creation of the corps of engineers known as the Reclamation Service, an organization under one of the branches of the U. S. Geological Survey. The operation of these engineers grows out of the passage of the Reclamation Act of June 17, 1902, setting aside the proceeds of the disposal of public lands to be used in survey and construction of irrigation works in the thirteen states and three territories of the arid region.

The development of this corps of engineers is a logical outcome of the work of the Geological Survey, and is the result of development along definite lines of research. The beginnings antedate the creation of the present Geological Survey, and are to be found in the reports of Major J. W. Powell, the pioneer in so many lines of research. His report on the lands of the arid region early attracted attention to the importance of irrigation, and when he became director of the Geological Survey he, through his strong interest in the subject, turned much of the work of the survey in directions which led to a larger knowledge of the opportunities of the creation of homes in the west.

In 1888 the director of the Geological Survey was authorized to investigate the extent to which the arid regions might be reclaimed, and appropriations were given with special reference to mapping the catchment areas of the principal rivers and obtaining a broad knowledge of the entire country.

In 1894 specific appropriations were had for stream measurements, and these were gradually increased, resulting in the operations of the

Hydrographic Branch of the Geological Survey. With the acquisition of facts concerning the rivers of the west, their fluctuations, the opportunities for storage and for diverting the waters upon arid land, came a more definite appreciation of the importance of the whole subject. The people of the United States, stimulated by the irrigation congresses and Irrigation Association, urged upon their representatives in congress the enactment of a law recognizing the conditions.

One of the first acts of President Roosevelt was to recommend the passage of a national irrigation law, and the intelligent interest shown by the president in directing and furthering the efforts of other public men culminated finally in the passage of the Reclamation Act. This

SALT RIVER, ARIZONA, AT DAM SITE OF PROPOSED TONTO RESERVOIR
The dam will be 240 feet high.

places at the disposal of the secretary of the interior a fund which now amounts to nearly $25,000,000 and is steadily growing.

Immediately upon the passage of the Reclamation Act the secretary of the interior authorized the director of the Geological Survey to utilize the services of the men who had been studying the subject, and to add to their number from time to time other experienced men, selection being made from competitive civil service examination. By these means the Reclamation Service has been gradually built up in the Hydrographic Branch of the Geological Survey, until now it includes about 250 engineers of various grades and classes, including men of wide experience in constructing and consulting capacities.

Young men, graduates from technical schools of good repute, are admitted for examination to the lowest positions and designated as hydrographic aids. As they demonstrate their ability and gain experience they are advanced to the position of assistant engineer, and finally to that of engineer. The service is organized on such a basis that the responsibilities are directly placed, and in matters of judgment the advice of consulting engineers and experts can be had.

The operations of the reclamation service began with a reconnoissance of the entire arid and semi-arid regions. The maps prepared by the topographic branch of the Geological Survey are utilized and the geologic facts which bear upon the occurrence of water above or underground are considered. In fact, every branch of scientific research

DRIVEWAY AT PHOENIX, ARIZONA. IRRIGATED PALMS.

which relates to the storage and use of waters is a subject of concern.

The principal work is, however, not merely to bring the facts together, but to put these to practical application in the construction of large hydraulic works, such as dams for storing the water in reservoirs, or diverting it from the rivers through canals or aqueducts for conveying it to arid lands. These works are carefully planned and the designs and specifications are passed upon by boards of engineers thoroughly familiar with the subject. When a district engineer, that is to say an engineer in charge of the operations in a drainage basin, has brought his work to a point where it can be passed upon, a project board is convened, the members of which have had broad experience in

designing and constructing under similar conditions, and who already know the essential local facts from personal observation.

The project board takes into consideration all the facts as to water supply, foundations and materials for construction, the design and operation of each part of the work, and the character of the lands to be supplied, the climatic conditions and innumerable details. After going over the conditions on the ground the project board prepares a brief report and recommendations, these being submitted through the regular channels for the approval of the secretary of the interior. When instructions have been received from the secretary contracts are prepared after advertising, in the usual fashion.

Work of construction has already been begun in Arizona, Nevada,

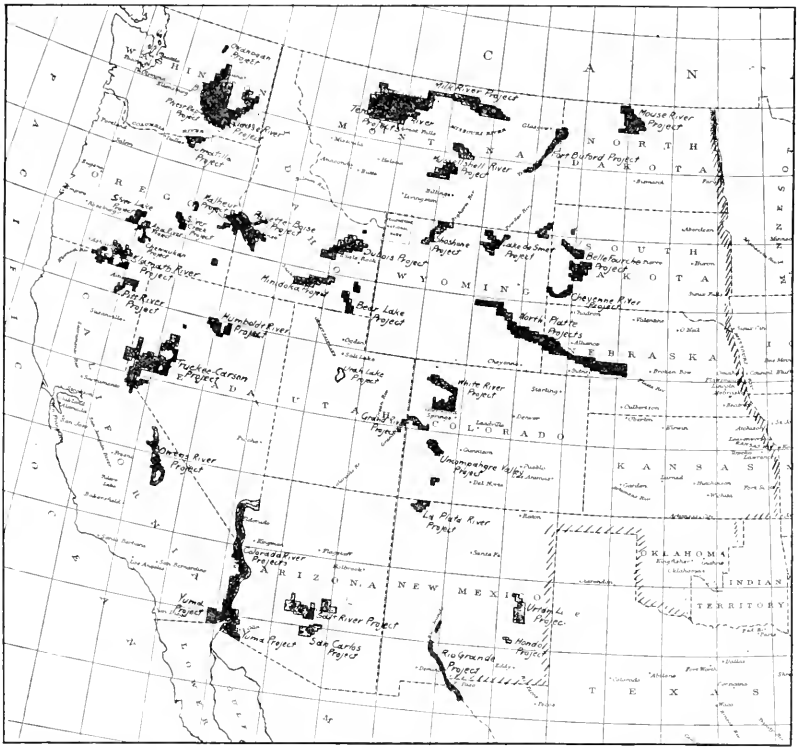
TYPICAL VIEW ALONG IRRIGATION CANAL, ARIZONA.

New Mexico, Colorado and Idaho, and will soon be taken up in other states and territories. In the two and a half years which have elapsed since the passage of the act the conditions in the west have been thoroughly considered, and already funds have practically been allotted to the more important and beneficial projects. The work has not only been on a large scale, but it has been necessary to establish many important precedents and to create institutions which are designed to last for centuries.

The Reclamation Act is very broad and leaves for executive discretion innumerable important details, but it guards carefully a number of points of possible failure. Discretion has been exercised with a

view to perfecting an organization to meet the demands of the future, and special attention has been devoted to securing the economical and efficient carrying out of the purposes of the law. It may be said that the early dangers are passed and that now the work is assuming something of a permanent or routine character, resulting from the experience already obtained.

The following list gives alphabetically by states and territories the principal projects in hand, the acreage which may be reclaimed, and the



PRINCIPAL RECLAMATION PROJECTS UNDER INVESTIGATION BY THE RECLAMATION SERVICE, OCTOBER, 1904, INDICATING APPROXIMATE AREAS WITHIN WHICH PUBLIC LANDS HAVE BEEN RESERVED. SLOPING LINES INDICATE EASTERN BOUNDARY OF RECLAMATION STATES.

estimated expenditures or allotments already made. It is not possible to give with precision the acreage or cost, as there are almost innumerable contingencies, and it has not been considered wise to delay in order to ascertain with great exactness all the conditions which may be met. For example, the acreage to be reclaimed may be more or less dependent upon legal conditions or land titles to be secured, and the area will also be modified when a more complete knowledge has been obtained acre by acre of the reclaimable lands.

In the column headed 'allotment' is given either the amount of money set aside by the order of the secretary, or the restricted fund, so called, which is to be expended in each state according to the feasibility of the project found. The Reclamation Act provides that the major portion of the fund shall be spent in the state or territory from which it originates if practicable. In a number of states where the question of practicability is under consideration, the restricted portion of the fund has been temporarily set aside pending definite action.

State or Territory.	Project.	Acres.	Allotment.
Arizona	Salt River	160,000	3,000,000
California	Yuma	100,000	3,000,000
Colorado	Uncompahgre	100,000	2,250,000
Idaho	Minidoka	130,000	2,600,000
Kansas	Pumping (?)	2,000	49,903*
Montana	Milk River	60,000	891,991*
Nebraska	North Platte	100,000	1,000,000
Nevada	Truckee	200,000	3,000,000
New Mexico	Hondo	10,000	240,000
North Dakota	Ft. Buford and pumping	60,000	1,737,111*
Oklahoma	Otter Creek (?)	40,000	1,301,590*
Oregon	Malheur	90,000	2,000,600
South Dakota	Belle Fourche	60,000	2,100,000
Utah	Utah Lake	20,000	154,199*
Washington	Palouse	100,000	1,395,035*
Wyoming	Shoshone	100,000	2,250,000
	Total	1,332,000	$26,970,429

In addition to the principal projects above listed, reconnoissance surveys are being carried on in each of the thirteen states and three territories, and alternative projects are also being examined with a view to construction if the principal projects, for any reason, are found to be impracticable. It is proposed to have these alternative projects carefully examined and ready for construction as soon as the principal projects are out of the way. The following paragraphs give briefly the present state of knowledge concerning each of the principal projects:

Arizona.—The Salt River project contemplates the storage of water for approximately 160,000 acres of land and the development of pumping facilities for an additional acreage. The cost will probably be about $20 per acre, and ultimately from three to four million dollars may be expended.

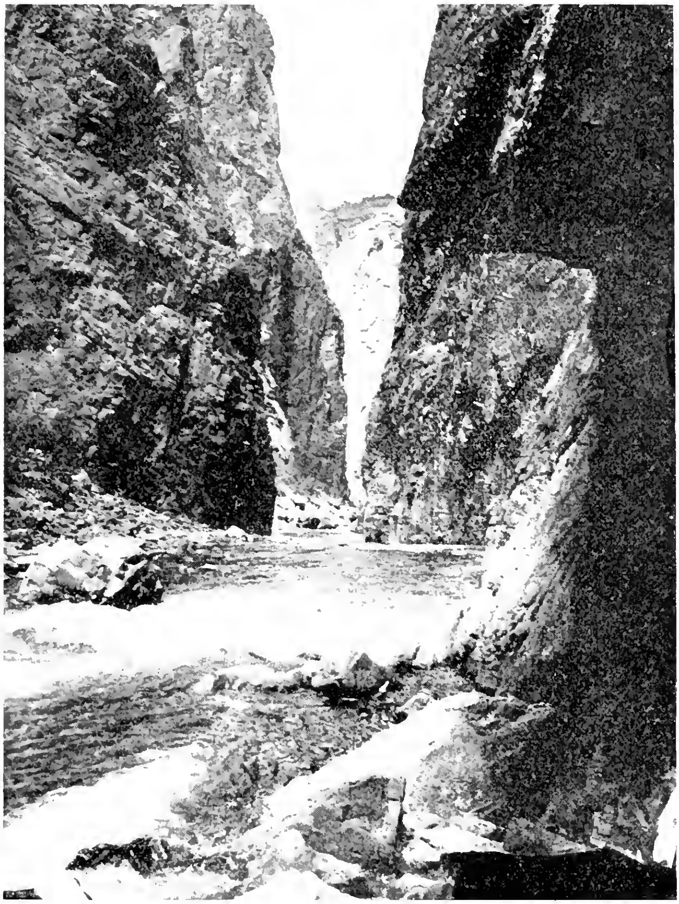
California.—The Yuma project, on the Lower Colorado River, as now outlined involves the reclamation of 85,000 acres at a cost of $35 per acre, the land being on both sides of the river in California and Arizona.

Colorado.—The Gunnison project contemplates the reclamation of 100,000 acres of land in the Uncompahgre Valley, at a cost of about $25 per acre. This land is largely in private ownership. The project

* Restricted fund.

involves the building of a tunnel from Gunnison River, six miles in length and requiring four years to build.

Idaho.—The Minidoka project is for the reclamation of 100,000 to 120,000 acres of vacant public land on both sides of Snake River, at a cost of $26 per acre. This is to be accomplished by the construction



Gunnison Cañyon near Head of proposed Diversion Tunnel.

of a dam and canals and development of the gravity and pumping systems.

Kansas.—Investigations are being made of the feasibility of pumping water in Kansas, and particularly of the quantity and rate of movement of the so-called underflow of western Kansas, and the practicability of bringing this to the surface.

Montana.—The Milk River project is for the reclamation of nearly 60,000 acres of land, mostly public, and located mainly on the south

TRUCKEE VALLEY NEAR WADSWORTH, NEVADA.
Truckee River will furnish part of the water for the extensive Truckee-Carson irrigation project.

side of Milk River, east of Malta, Montana. The cost will be from $20 to $25 per acre.

Nebraska.—North Platte project is for the reclamation of an undetermined area of land east of the Wyoming boundary and the building of a canal on the north side of North Platte River. Some of this land is now in private ownership. The cost of reclamation will probably be between $35 and $40 per acre.

Nevada.—The Truckee project now under construction will reclaim upwards of 150,000 acres at a cost of about $25 per acre. There are a number of ramifications which are yet to be worked out and these may result in a larger development.

New Mexico.—The Hondo project in the vicinity of Roswell will irrigate about 10,000 acres, a portion of which is in private ownership. The cost will be upward of $25 per acre. Water is to be obtained from flood storage in a reservoir to be constructed on the north side of Hondo River.

North Dakota.—Fort Buford project is to reclaim 60,000 acres of lands on the west side of Yellowstone River in Montana and North Dakota, at a cost of about $30 per acre. Most of this land is in private ownership.

Oklahoma.—In this territory investigations have been made of the opportunity of storing water in a number of shallow basins, but as yet the results have not been satisfactory.

Oregon.—The Malheur project, on both sides of Malheur River, west of Ontario, will reclaim, by a storage of flood waters of Malheur River, about 90,000 acres at a cost of about $30 per acre.

South Dakota.—The Belle Fourche project contemplates the reclamation of 60,000 acres of arid land, largely public, situated northerly from the Black Hills. This is to be accomplished by the storage of flood waters of Belle Fourche River. The cost will be about $32 per acre.

Utah.—The Utah Lake project contemplates the utilization of waters tributary to Utah Lake and the reduction of evaporation losses by drawing down the lake. It is possible that 20,000 acres may be reclaimed at a cost of $35 per acre.

Washington.—The Palouse project is for the reclamation of arid lands near Pasco, by storage in Washtuena reservoir. Possibly 100,000 acres, mainly in private ownership, can be reclaimed at a cost of $35 per acre.

Wyoming.—The Shoshone project is for the reclamation of 100,000 acres of public land in the Big Horn Basin, north of Shoshone River. Water will be stored and diverted at a cost of $25 per acre.

Most of the systems for irrigating land depend wholly upon the gravity supply of water, but in a number of localities it will be neces-

sary to use pumps. For this purpose plans are being made for the development of water power and the use of this in pumping by electric transmission. It is believed that in this way considerable areas of desert land can be reclaimed which are now out of reach of water obtained by the usual methods. Scientific investigation is being pushed along these lines, and also in many other directions, and of the employment of cement and concrete in construction. In short, the scientific work, while subordinated to the so-called practical side, is receiving constant attention from the various experts.

Assistance is being given to the reclamation service by the operations of the other divisions of the hydrographic branch. These are three in number: first, the division of hydrography, which has to do with the scientific measurements of the flow of the streams; second, the hydrologic division, which is studying the hydro-geology, or the bringing together all the facts bearing upon the occurrence of water in its geologic relations, and third, the hydro-economic division, which has to do with the quality of water and the relation which the changing qualities have to the industrial uses. In particular the quantity of saline matter carried in solution is of prime importance to the question of irrigation, and next to this the character and amount of material carried in suspension.

The operations of the Hydrographic Branch, including the Reclamation Service, illustrate the evolution which may take place under suitable auspices from the small beginning of a scientific investigation, leading up step by step to the practicable operations of applied science in building great works to endure for centuries. It is significant of modern times to find the engineers and scientific men taking a larger and larger part in the executive business of the world, and bringing to it the training of the technical school and laboratory, as distinguished from that of the counting-house or lawyer's office.

CHINESE AND JAPANESE IMMIGRATION.

BY DR. ALLEN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE.

ABOUT twenty years ago the tide of Chinese coolie laborers assumed such proportions that the Chinese exclusion act was enacted to protect the Pacific states from the horde of yellow parasites which threatened their prosperity. The radical step of legislating against a race was taken after due deliberation, and recognition of its urgent necessity. The Chinese exclusion act has worked fairly well, and in 1901 was reenacted. It is not perfect, and evasions have been frequent, as might be expected in a people fertile in resource and schooled in trickery and deceit, as are the Mongolians, but on the whole the object aimed at has been attained. It has kept out the mass of yellow coolies who would otherwise have come here, and has practically confined the question of Chinese coolie labor to the Pacific coast, whereas, without it, we should have had the coolie labor in Illinois, Pennsylvania and every other state in the Union.

One of the many methods employed by Chinese in evading the exclusion law is of particular interest because of its bearing on illegal naturalization of aliens. Naturalization of Chinese is often an incident of a successful attempt to evade the Chinese exclusion law. A Chinaman arrested in crossing the Canadian border will claim he is a native of the United States and is able to produce Chinese witnesses who will swear to his nativity. He is not only admitted, but is admitted as an American citizen—and his children born in China will also be entitled to admission to the United States and undoubtedly in time will also claim citizenship. An officer detailed to examine the conditions existing upon the Canadian border, in his report to Hon. F. P. Sargent, Commissioner-General of Immigration, makes the following statement, published in the 'Commissioner-General's Report' for 1903:

HON. F. P. SARGENT,

Commissioner-General of Immigration, Washington, D. C.

Sir: . . . To acquaint myself with all that might bear on the subject, I called at the Chinese bureaus at New York and Boston, conversed with the Chinese inspectors and interpreters, attended the trial of cases at Ogdensburg, interviewed the Chinese themselves at different points in their own language, read whatever notices I saw in Chinese, called at their stores, schools, restaurants and laundries, and at every opportunity gathered what information I could on the subject.

I found that in this section of the country Chinese gain admission into the United States by smuggling, by applying openly through the regular channels as members of the exempt classes, or by surrendering themselves a short distance from the border for arrest and trial, as a rule, under the guise of being natives of the United States. As to the first-mentioned class, the number is being reduced, owing to the constant vigilance of our officers on both sides of the border. As to the second class, the inspector in charge of the Brooklyn district, as well as the one in charge of the Boston district, I found to be good, efficient officers, and cases are submitted to a thorough investigation. It is the third class—that of the so-called 'natives'—that calls especially for correction. There are several points near the Canadian border, such as Malone, Ogdensburg, Plattsburg and Rouse Point, where Chinese of the class last mentioned are taken for trial. This class comprises Chinese who have come from China and have camped at Montreal, until such time as the members of the ring engaged in working up their defense could secure witnesses to testify to their alleged nativity.

I attended the trial of several such Chinese, on whose behalf the claim of being natives of the United States was made, which, I was creditably informed, fairly illustrated the usual method of trying this kind of cases. At the time set the case of Ah Sing or some other Ah would be called, and with the defendant absent from court throughout the whole session one other Chinese would be put upon the stand to testify to the defendant's having been born in the United States—most likely in the Chinatown of San Francisco, the alleged birthplace of tens of thousands of others that have made the claim at various times and at various places before him. Upon the uncorroborated testimony of this one Chinaman the other Chinaman, awaiting the issue in jail, would be declared a native of the United States. This goes on week after week and month after month, and has been going on for years. One of the Federal judges estimated that if the story told in the courts were true, every Chinese woman who was in the United States twenty-five years ago must have had at least 500 children. (Report of Proceedings of Chinese-Exclusion Convention, held at San Francisco, November 21 and 22, 1901, p. 51.) By this method thousands of Chinese—upon the admission of the Chinese themselves—have been allowed not only to enter and remain in the United States, but declared to be native-born citizens thereof, each with a vote and qualified to participate in the political affairs of this country.

How far-reaching the effect of such a method is can be appreciated only when it is borne in mind that not only the Chinese who may be thus admitted are made citizens, but also their alleged children, though born in China.

That Japanese are naturalized illegally is shown by the report of special examiner C. V. C. Van Deusen, published in the 'Report of the Attorney General of the U. S.,' 1903. Mr. Van Deusen says:

Notwithstanding the fact that the Federal statutes exclude from the rights of citizenship all persons except free white persons and those of African nativity and descent, courts have admitted to citizenship persons not belonging to either of those two races. This is particularly true of courts on the Pacific coast, which have naturalized many natives of Japan, and the clerks of which still continue to accept from such persons declarations of intention to become citizens. As several of these clerks have admitted to me the fact that they know that the naturalization laws exclude Japanese, their demand for an acceptance from these people of the naturalization fees brings them dangerously close to the penal provisions of statutes bearing upon unlawful practises.

The Japanese has never been placed under the ban to which his Mongol brother, the Chinese, is subjected, because not until recently did Japanese immigration reach proportions of alarming size. The rapid increase of Japanese immigration is shown by the table given below.

Years.	Japanese Arrived.
1898	2,230
1899	2,844
1900	12,635
1901	5,269
1902	14,270
1903	19,968

The Japanese coolie labor is (according to some observers who have made a special study of them) more undesirable than the Chinese. There are thousands of these Japanese working in the orchards, vineyards, gardens, hop and sugar-beet fields of California.

The investigations of the California State Labor Bureau show that the Japanese usually come here in gangs of twenty-five or more, and are controlled by Japanese boarding-house keepers in San Francisco, Seattle and other Pacific ports, the system resembling the 'padrone system' of the Italians. These Japanese boarding-house keepers or bosses are in touch with so-called 'Immigration companies' in Japan. Mr. Thos. F. Turner, in his able report upon Chinese and Japanese labor in the mountain and Pacific states, prepared for the Industrial Commission, and presented by it to Congress, December 5, 1901, says:

A contract is entered into by one of these immigration companies with every Japanese immigrant coming to the United States By the terms of the contract it is provided that the immigration company shall secure passage for the immigrant to the United States, with necessary passport, and that it shall provide for all his creature comforts while *en route*, and return him to Japan in case of sickness. Fully 80 per cent. of all the Japanese who come to the United States are classified, as shown by the reports of the immigration office, as farmers. The wages of farm hands in Japan are 3 to 4 yen per month, or about $1.50 American money, without board or lodging; yet every one of this class of immigrants, after paying passage to the United States, is able to show to the immigration officer $30 in gold. It is understood by the immigrants that they must have at least this amount in order to secure landing in the United States.

It is a fact full of significance that of the hundreds of coolies who are constantly coming into the United States every one produces just $30 in gold; no more, and no less.

That the entire system of immigration companies, boarding-house keepers and Japanese bosses is but an elaborate and ingenious method of avoiding our contract labor laws, no one who has investigated the subject can doubt.

The following is an exact translation of one of the immigrant contracts referred to:

CONTRACT

The Nippon Imin Goshi Company will contract, accepting the request for transportation, of Yoshida Ichitaro, who is a free emigrant, having the purpose to land in San Francisco, North America, and to secure for him work there, within the limitations prescribed by the immigration laws.

1. The emigrant shall perform everything that is needed for getting the passport and must be responsible for all expenses needed for the voyage, and should have the money which is necessary when landing.

2. The maturity of the contract is three years from the date that the emigrant starts.

3. If the emigrant gets sick, or loses the means to get along, Narita Toyashira, agent, will help him and provide him means to get back to Japan in case it is necessary.

4. If the emigrant is sent back at the expense of the Japanese government the company shall pay all the expenses for the emigrant.

5. The emigrant shall pay 10 yen to the company as its fee. If the emigrant has a child who does not exceed the age of 15 years, the charge for it will be half price, and if the child is not exceeding 10 years of age, he will be carried free of charge.

6. The emigrant shall provide two securities to the company according to acts 3 and 4 thereof, and they will be responsible to pay all of the expenses that have been paid by the company under the provisions of sections 3 and 4.

7. The two securities are responsible in all the matters pertaining to the emigrant.

This contract is made in duplicate, one to the emigrant and one to the company.

Meiji, 31st year (1898), 1st month (January), 31st day.

HAMANAKA HACHITARO,
Special Manager Japan United Immigration Company.

Emigrant:

YOSHIDA ICHITARO,

Securities:

YOSHIDA YOHEI.
YAMAMOTO KUSU.

There is every ground for the belief that the $30 which is exhibited by the immigrant to the United States officials is furnished by the immigration company. The whole scheme is a flagrant violation of our contract labor laws. The class of Japanese immigrants who are thus enabled to come to the United States are of the most objectionable character, and without the assistance of such organizations would be compelled to remain in Japan. The United States Government should take immediate steps to suppress these immigration companies.

The great danger to the laboring interests of the United States of unrestricted Japanese immigration will be better understood after an examination of the following table showing the prevailing rate of wages paid in Japan in the various lines of industry:

JAPANESE WAGE RATES PER DAY.

	* Yen.	United States Money.
Carpenters	0.55	$0.26
Plasterers	.55	.26
Stonecutters	.65	.31
Paper-hangers	.50	.24
Joiners	.60	.29
Tailors for Japanese clothing	.50	.24

* A yen is valued at 48 cents.

	Yen.	United States Money.
Tailors for foreign clothing	1.00	.48
Blacksmiths	.75	.36
Printers	.40	.19
Ship carpenters	.60	.29
Compositors	.60	.29
Common laborers	.40	.19
Confectioners	.35	.17
Farm laborers, per month	3.00	1.44

It is little wonder that these strange foreigners, when they come to the United States, are willing to work for 60 and 70 cents a day, which is more than double the wages for which they were compelled to work in Japan. As a result of this unnatural competition the white laborer has been driven from the field wherever the coolie system has found a foothold.

The Japanese adopts our dress and manners, but his Americanization never extends beyond external appearances. The yellow and the white races are as immiscible as oil and water. No forces of education or civilization can make aught but an Asiatic out of a Chinese or a Japanese. There can be no assimilation, nor do they desire it. They simply intend to hoard a certain amount of American gold and go back to Japan or China to pass the remainder of their lives in comparative ease. While here, their one idea is the hoarding of money; to earn as much and deny themselves as much as is compatible with human endurance. They have no interest in our government, in our laws or in us, other than that which concerns the attainment of their object.

Aside from the economic aspects of Japanese immigration, there is one other objectionable feature of this second yellow invasion which is worthy of note. They bring more cases absolutely and relatively of contagious disease than any other nationality coming here. During 1903, one Japanese out of every 37 arrived was deported as afflicted with a loathsome or dangerous contagious disease. The coming of the Japanese merchant, professional man or student should be permitted, just as we now permit the same class of Chinese to enter freely, but the coolie laborer, whether Japanese or Chinese, is an unfair competitor for our white laborer, and with his high percentage of disease is an element of danger to the public health.

THE STATUS OF AMERICAN COLLEGE PROFESSORS.

By Professor JOHN J. STEVENSON,

NEW YORK UNIVERSITY.

THREE months ago, the colleges and universities opened for the new year. In most instances, telegrams from the institutions were jubilant, announcing that the entering class is the largest in the history of the college, but some were apologetic, as one or another department showed decrease. Editors rejoiced in the 'era of education,' pointing with pride to the four hundred and fifty colleges, more or less, with about 15,000 instructors and about ten times as many students and a total income for all purposes approaching $25,000,000. Unquestionably, there is much in this of which to be proud, but the broad statement, as given in the journals, fails to emphasize the fact that this great fabric of higher education owes its existence, in great measure, to the willingness of college professors to bear a great part of the cost. It is true that college professors have never received salaries such as to arouse envy in men of other professions, but, at one time, the calling offered great attractions to those who cared more for study than for money. Appointments were made for life or good behavior, the calling was honorable above all others, as in Germany of to-day, and there was that 'literary leisure' which could be devoted to investigation. Many imagine that there has been no change in these conditions; this error should be corrected.

The scope of instruction, especially on the scientific side, but measurably on all sides, has been widened and the hours have been scattered so as practically to cover the available day. The kind of knowledge required is very different from that of even thirty years ago, when students had hardly any source of information outside of the text-book and classroom and the courses were truly elementary. Immediate preparation required little time and the professor's close study was within a chosen field of investigation; but now he must read carefully the literature in all portions of the field covered by his chair merely to meet the exigencies of the classroom, for the elementary courses of little more than thirty years ago belong to the common stock of knowledge; popular magazines deal with discoveries in science and archeology, as though they belong to familiar discourse, and daily papers indulge in editorial discussions of subjects which, twenty-five years ago, were in the province of specialists alone. There remains for the college professor hardly a trace of 'literary leisure,' and even the university professor is apt to find the stress of outside duties con-

nected with his work so exhausting that, during term time, any prolonged study beyond that which is necessary becomes irksome.

Two generations ago, college trustees kept themselves more or less in touch with the professors and made diligent effort to become familiar with details of the work. With vast expansion in resources and equal expansion in the curriculum, personal relations between professors and trustees practically ceased and the latter have no longer time, opportunity, or, in too many cases, inclination, to acquaint themselves with the nature or extent of the work done by individual professors. University faculties have rarely any direct representation in the board of trustees or before it, the common mouthpiece being the president, who, no matter how earnest and faithful he may be, is not, in the very nature of things, competent to understand all matters or to present them properly. In too many cases, the professors are not consulted even in the matter of appointments and the trustees place the responsibility for these upon the president, as though the institution were a country academy. Naturally enough, trustees have come to regard themselves as the institution and the professors as merely their employees, as, indeed, has been asserted. This has gone so far that in one institution, at least until a very recent period, all appointments were for the period of one year—a plan admirably adapted to secure adherence to the powers in control. For trustees having this conception of their powers and duties, the usefulness or worth of an instructor is not measured by his ability as teacher or investigator.

Certainly the attractions making the profession so inviting in former days no longer exist in such form as to be magnetic to ambitious young men.

It might be supposed that, on the whole, salaries have been increased so as to compensate in some degree for the losses; and the relation of income to number of instructors, as given in the opening paragraph, appears at first glance to confirm the supposition. But not so. Salaries, always small, have not been increased to keep pace with cost of living or even with other demands unknown two generations ago. On the contrary, taken as a whole, the salaries have decreased. The writer recognizes that salaried men are at a disadvantage in comparison with ordinary wage-earners, the advance of salaries being slow and the periods of rest usually long; but college men are at especial disadvantage owing to peculiar conditions, which have been intensified during recent years.

College income must come mainly from endowments or their equivalent. Students' fees, though not unimportant, pay but a small part of the cost. Little more than two generations ago, when college faculties were small, the course compulsory and free tuition almost unknown, fees were the chief source of income. With increase in number of students, old buildings became insufficient and new buildings were secured by sale of long time scholarships at low rates, the future

being heavily mortgaged for the present. After the civil war, a vast army of students entered our colleges; the fees were increased somewhat in many cases, but not in proportion to the cost, and the system of free scholarships became an important feature almost everywhere. More buildings, more and attractive grounds, were acquired and in time a large share of the income went toward mere maintenance of the property. To make matters worse, the colleges soon suffered an actual loss of income, for owing to the decreasing rates of interest, the endowments, such as they were, became less and less productive, while, in addition, the broadening of the curriculum compelled greatly increased expenditure. Fifty years ago there were institutions doing excellent work for the times with only six or seven salaried men in the faculty, averaging one instructor in some cases to forty students, whereas to-day the multiplicity of courses requires an instructor to every ten or even less students.

Increasing outgo without corresponding income must be at somebody's expense, and, in this case, that somebody is the college instructor. Not that in every case the salary of a professor has been reduced in order to pay the cost of dividing his chair, so that the college may receive twice as much work for the same money—though this is not unknown—but that a newly appointed man in many cases receives less salary than his predecessor. It is by no means rare for a college, on the retirement of a professor, to divide the chair, employing young men at salaries which, combined, amount to little more than the single salary fixed many years before. Even so, not a few of our colleges have alarming deficits at the end of each year.

No doubt this arouses astonishment and some may be disposed to ask, in view of the immense gifts for educational work made during the last twenty-five years, if such a condition of things does not prove incompetence in the business management of colleges. Not at all; the error is not in that. The financial management, in most instances, is beyond criticism, more, it deserves the highest praise, and in many institutions the trustees are not merely competent, they are devoted and conscientious, dealing with college business as with their own. As the most caustic reflections upon college management usually come from alumni, the writer may be pardoned for a slight digression.

Alumni who contribute a few dollars a year toward the support of alma mater's glee or athletic clubs are apt to take their display of affection altogether too seriously. They seem to feel convinced that by attending the college and by securing a degree, whether deserved or not, they have placed their college under such material obligation that they should have a large voice in its control. This notion, which would be grotesque were its effects not so serious, is due perhaps to the constant hunt for students and to the prevalent opinion that the success of a college is measured by the number in attendance. But the

college is under no obligation whatever to the alumnus; its obligations were all discharged when he graduated; on the other hand, the student's pecuniary obligation increases each year, reaching its maximum at his graduation. This matter can not be presented too frequently or too emphatically.

An excellent man of large means once informed the writer that he would never send his grandson to a college in which tuition is free, as he always paid for what he received. He was taken aback when told that, although paying a large sum for his grandson's tuition, he was still an object of charity to the extent of several hundred dollars a year, the cost per student at that institution being, as the writer knew, four times the fee. It is probable that in no college to-day is the cost less than three times the fee, and in those with small fees the cost is proportionately very much greater. Before giving voice to a demand for a share in control of college affairs, the alumnus will do well to discharge the debt of $1,000 to $1,500 which he owes to 'dear old alma mater.' Were alumni to do this, the pangs of poverty would be less severe in many of our colleges.

Returning from this digression. It is very true that immense sums have been given to colleges and universities during the last thirty years and that such giving is likely to continue. Much of the money thus contributed was for the founding of new institutions, too often with inadequate equipment, thus making the condition worse by adding to the number of struggling colleges; much was given for the erection of buildings, most of them needed, but not in all cases useful in proportion to the cost and, until recently, not always endowed; much has been bestowed upon the endowment of scholarships; not a little has gone toward the founding of fellowships for the encouragement of graduate study; some large sums have been given for the advancement of outdoor athletics and intercollegiate contests; and in many cases funds have been provided for the employment of instructors in new branches. But unconditional gifts of money have made up only a small part of the whole, and even where these have been given, those in charge of affairs have rarely seen fit to strengthen the institution by increasing salaries, preferring rather to 'expand' by creating new chairs to be filled by young men at, to speak within limits, modest salaries. In all probability, there are institutions with a net endowment not so great as it was thirty years ago, though showing a great increase in number of students and instructors as well as in property. The average salary is much less and the president's energies are devoted to raising money to meet the annual deficit. So it has come about that the college president of our day has duties very different from those of thirty years ago. The loss of the old-time president has been a disaster and the good of our colleges requires that he be brought back. There should be an officer at the head of the business affairs and

another at the head of the educational affairs. Our universities will not do their work as it should be done so long as the two offices are held by one man.

Some excellent people who have no money, and others who have money but do not give, are quick to censure those who donate buildings instead of funds. College men, being especially affected, are apt to repine much after the fashion of a good professor, who, in speaking of a generous benefactor, said, 'We asked him for bread and he gave us a stone.' But the criticism is unjust. Donors are said to be selfish, seeking only to perpetuate their names. Even so, they have done only what every man ought to do and they have chosen a praiseworthy method; they will be remembered as doers of good. It must not be forgotten that the steady stream of buildings had its origin in the most pressing need of our colleges. At the close of the civil war, colleges had their faculties and the professors were receiving fairly good salaries; but there were not buildings in which to accommodate the rapidly increasing number of students and every effort was devoted to supplying this crippling deficiency. When, later on, it became necessary to add to the staff of instructors, the older professors gladly consented to the lessening salaries, expecting soon to have the conditions restored, but never suspecting that by enduring hardness for the sake of their institutions they were making a standard for the future.

But now, in most of our colleges, additional buildings are not the urgent need; the time has come to impress upon the community the necessity for endowments, that qualified instructors may be obtained so as to utilize properly the buildings and equipment already provided so generously. Buildings are necessary, but they do not make the college, no matter how complete their equipment may be. The college is not here to cultivate public taste in architecture or even to restore the Grecian games; primarily, its purpose is to train men for life's struggle; secondarily, to advance the world's welfare by investigation. Without a thoroughly efficient staff of instructors, the college is a farce, no matter how magnificent its plant may be, how numerous the students or the victories in athletic contests. The prolonged effort to obtain buildings has obscured this fact, and now, with increased cost of maintaining grounds and buildings, with increased and increasing number of instructors to satisfy incessant demands for new courses—which those in authority have not the moral courage to deny—with constantly increasing numbers of students and with practically no compensating increase of income from endowments, the ability of colleges to pay salaries deserving of the name has disappeared. Nowhere in the United States are there salaries which mean more than a very modest living. It is true that a few salaries in the larger cities are such as to appear enormous to those living in small villages; but even those are larger only arithmetically, not in purchasing power;

while they are far more than counterbalanced by the great number of small salaries in the same institutions. These 'large salaries' in themselves are not such as to be inviting to strong men; they are inviting, however, because with them there is offered also some of that 'literary leisure' which is so much desired by the student.

As the result, college chairs are filled in great part by men who, at the most, are but partially dependent on their salaries. In a sense, this was always true. When the hours of teaching were less scattered and the requirements less severe, college men in cities often supplemented their salaries through congenial work outside; while in country colleges, where an almost prerequisite qualification for several of the chairs was ordination to the christian ministry, professors added to their income by preaching. But those conditions no longer obtain, and in some institutions a professor, even if he have the opportunity, may not undertake any outside work without special permission—a perfectly proper regulation. In any event, except in rare instances, no opportunity remains for a professor to engage in outside work during the college year unless he devote only a part of the time to college work, for, as already said, practically the whole business day is demanded. To live in comfort, to retain the respect of the community, one must depend largely on means already acquired.

That this condition, or, rather, combination of conditions, will have a prejudicial effect on the personnel of the profession is not open to doubt; and additional danger lurks in the system of fellowships, which is nothing other than that of hiring young men to pursue graduate studies. Even now, though the system is, so to speak, in its infancy, graduates judge of universities not so much by the standing of the professors or by the grade of instruction offered, as by the value of the fellowships. Students about to graduate have been known to ask their professors what inducement the college offers them to remain—more than that, have been candidates for appointment at more than one institution. Evidently the time approaches when prospective candidates for the doctorate will scan university catalogues as prospective students of theology are said to scan seminary catalogues, to discover which has the longest list of highly productive scholarships.

Formerly a graduate desiring to become a professor usually received appointment at once as a tutor and eventually worked up into some professorship. That was when the courses were all somewhat elementary in character; but now special preparation for a particular chair is demanded. The graduate spends at least three years in study as a specialist, very frequently including a year or more at some European university. On the scientific side, at least, this work is severe, leaving no time for other occupation except at the cost of a dangerous expenditure of energy. Preparation for college teaching

is more exacting than that for any other profession, medicine not excepted.

The prospect of spending seven years in preparation, of working afterwards as an assistant for several years at a salary of $700 or $800, for several years more at a small advance, and of attaining by middle age a salary not much greater than the wages of a switchman in an eastern railway yard, with at the end little hope of a pension is by no means alluring to a man unwilling to remain celibate throughout life. Thoughtful young men in the higher classes of our colleges recognize this condition and recognize also that the compensating privileges of social standing and leisure for research have been reduced to the minimum. This feeling respecting the status of American professors is so widespread that, unless the conditions are modified quickly, the next generation will see a notable change in type of professors; some will be teachers because unwilling to be anything else; some will be men of independent means desiring a not too burdensome occupation; but a large proportion will consist of men carried along on scholarships and fellowships into a profession for which they have neither fitness nor inclination—perfunctory teachers, lamenting their fate in being compelled to 'waste themselves on a parcel of boys.'

To prescribe a remedy is not difficult; to bring the patient into receptive mood is apt to be difficult. The writer suggests a remedy; the administering must be left to others.

The first step should be elimination of mimic universities and restoration of the college with a fixed curriculum, intended to develop the man and to lay foundation for a broad education. By thus removing odds and ends of elective courses and attempts at types of work belonging altogether to graduate study, relief will be given from much which is of doubtful utility to the undergraduate, and the professors will regain that leisure, which for so many years was utilized to the advantage of the whole community.

The second step should be complete readjustment of the relation between the corporate and educational boards. Times have changed and with them the conditions also, but the powers and duties of the corporate board have remained unchanged. Trustees are chosen in view of their fitness to manage the financial affairs, very rarely with reference to their familiarity with educational matters; yet their board has, as of old, the power to appoint professors and even to create new chairs, thus controlling not only the selection of the faculty but also the curriculum, matters with which, in the very nature of the case, they cannot deal intelligently—as a board. The teaching board should have the sole right to name candidates for appointment, to determine all matters concerning the curriculum and the corporate board should be called upon to confirm the action, *pro forma,* whenever a business contract is involved. Details respecting methods of procedure do not

concern us here; what is contended for is a proper assignment of powers and duties to accord with the conditions of to-day as contrasted with those of two generations ago, when most of the great institutions of to-day were little better than are the eastern High Schools. This adjustment would give to the teaching staff its proper standing and the trustees would be guardians of the material interests.

Perhaps this second step should be regarded as the first. It certainly would change in some respects the estimate which some boards entertain regarding the relative importance of trustees and professors. In many colleges, professors have given their services at small salaries, far less than they could have obtained in other directions, have refused calls at higher salaries to other colleges, in not a few instances have reduced their salaries voluntarily and served the college for a pittance, simply to preserve it from destruction. All this they did deliberately, hoping that in the end their college would be placed upon a sound basis and depending upon the good sense of the trustees for proper recognition in due season. Such contributions should be accepted as so much money given annually to preserve the college and the contributors should receive at least as much credit as do such trustees as pay something in actual cash. That this is not the case is well known. When money is received by a college, the trustees should not hasten simply to relieve themselves from their subscriptions, they should share the relief with the professors; and if, at length, sufficient money should come to relieve the actual pecuniary stress and to leave a surplus, common honesty requires that that surplus be devoted toward finally relieving the professors. That done, the time will have come to consider the question of expanding the curriculum and of appointing new instructors. That this is not the view held by trustees of our day is a familiar fact. And yet the condition does not justify any reflection upon the honor of the trustees; it is due solely to the fact that they know little about the professors as men or as workers,—to the constantly widening gulf separating the corporate and educational boards.

In any event, this second step, if taken, would go far toward restoring the profession to its former honorable standing and would go far also toward making possible the third step, which is consolidation.

There are too many academies calling themselves 'college' or even 'university,' with high grade curriculum and low grade requirements, with long lists of pupils in preparatory classes of one sort or another and very short lists of students in so-called college classes. Many of these have no apology for existence aside from the fact that otherwise the religious denomination, which they represent, would have no educational institution in the region. There are in proximity too many feeble colleges, with few college students, with insufficient equipment, with practically no endowment and with makeshift instructors. If a judicious consolidation could be brought about, if the

academy portions could be gathered into a strong academy and the college portions into a strong college, with the academy as its feeder, if higher institutions under similar relations of space could be brought together so as to make a thoroughly equipped college and a thoroughly equipped university, the vast sums now expended on mere maintenance of property could be applied directly to educational work and a long advance would be made toward paying salaries which, with the regained leisure and the regained honor, would make college teaching once more attractive to men of the highest type.

The writer has been told that these propositions are fair and reasonable, that they are merely what common sense demands, but that they are chimerical. One correspondent asserts that they are good but that the world can not go backward. This last is very true, but the truism has no bearing upon the question. If one have strayed from the road in blind trails, he can hardly be reproached for retracing his steps to the parting of the ways, that, taught wisdom by his error, he may advance anew and along the right path.

That the suggestions are chimerical, the writer can not concede; that they involve serious difficulties, he not only concedes but also asserts. The obstacles to be overcome before the second can be realized are comparatively insignificant. If it be a common sense proposition, it will need only proper presentation to secure its acceptance by the business men on the corporate boards and, as far as they are concerned, the adjustment could be effected very rapidly. But obstacles of no mean sort will be encountered in an effort to realize the first and third, most serious of which are those arising from denominational prejudice or jealousy. Almost as serious are those due to individual prejudice or obstinacy. Trustees and teachers are unwilling to acknowledge that their college has no good reason for separate existence, though they know and the community knows that they know the fact. Alumni, whose only manifestation of interest in the college has been an occasional visit to a summer re-union, are apt to display a sudden and emphatic love for *Alma Mater* when consolidation is suggested, putting forth energy enough against consolidation to place the college on a good footing, if properly directed. The writer recognizes all of these difficulties, but is convinced that they will be overcome if only full discussion of the matter can be had, so as to bring it fairly to the attention of those on whose gifts the American college depends for development.

A DECADE OF LIBRARY PROGRESS IN AMERICA.

BY WILLIAM WARNER BISHOP.

AMONG the many gatherings of specialists which were held in connection with the Chicago Exposition in 1893 was an International Congress of Librarians. The account of its sessions appeared, in the usual belated manner of government publications, in the Report of the Commissioner of Education some three years later. The American Library Association has just held another similar international congress for the St. Louis Fair. It seems a fitting time, in view of this event, to set forth as well as may be in brief compass the events which have made the ten years which have elapsed since the World's Fair at Chicago a memorable decade in the history of American libraries.

It was a saying of President Garfield's that American education runs too much to bricks and mortar. A biting sting of truth lies in these words, truth which applies but too well to the library world in common with that of education. It is perhaps a national failing to exalt the visible and tangible, and to ignore the subtle and unseen work of culture and study. Undoubtedly the average man will turn to the new buildings which have been reared in this decade for his criterion of progress in library affairs. They form, it must be said, a notable addition to the list of public buildings of merit in the country.

Perhaps it is not too much to say that the modern American library is a new architectural type. Conditions peculiarly our own, many of them the direct result of American innovations in planning library work, have produced a kind of building which is in many respects novel. The college gymnasium and the large library in the hands of our architects have become almost as markedly American forms of building as the sky-scraper and the grain elevator. The demands of the librarian for natural light throughout the structure, for compact storage and at the same time for instant accessibility of his books, for protection from fire and damp, joined with the need of supplying plenty of space for readers, for administration and for those who throng the corridors and desks where books are given out and returned, have resulted in some extremely interesting and beautiful buildings. More and more architects are studying the needs of libraries, and mistakes once made and realized are seldom repeated.

The small library also has furnished in the past decade numerous

opportunities for the designer. Aside from the benefactions of Mr. Carnegie, which are in some respects the most striking event of the past ten years, literally scores of small buildings have been erected by private individuals and by towns. These are coming to form an architectural type fully as distinct as the large buildings. As a rule, of late years these smaller library buildings have taken the shape of a rectangular structure with a central hall, two large front rooms, a delivery desk across the hall and shelves in 'stacks' in the rear on the main floor. A second story usually provides space for additional study and administration rooms. A very large number of memorial libraries of this general type have been erected, particularly in New England. Numerous local and individual variations occur, but a building designed to shelve some ten thousand books so as to be easily reached by any visitor and to afford one attendant a fair view of the main floor has become the accepted type of the small library.

In 1893 there were but three examples of modern library buildings of a size much above the ordinary to be seen in America. These were the Boston Public Library, the Library of Cornell University and the Newberry Library of Chicago. All these are dignified and imposing structures, while the Boston edifice is distinctly one of the foremost public buildings of the country. No one of these buildings has ever satisfied librarians as an ideal, despite their abundant merits. In the past decade a round dozen structures have been reared, which undoubtedly rank as of the first order for size and cost. They are the Library of Congress, the Carnegie Library of Pittsburgh, the Public Libraries of Chicago, Milwaukee, Providence, Newark and the District of Columbia, and the libraries of Columbia, Princeton, New York and Illinois Universities, together with that of the State Historical Society of Wisconsin. Each of these buildings is in itself a notable production; as a group they form a striking testimony to the extent and vitality of the library 'movement' in this country. None of them is without individuality. The reading room of the Library of Congress, the rotunda and impressive south façade of the Columbia Library, the Hall of Fame at the rear of the New York University Library, are characteristic features known to all readers of the illustrated papers. The others offer even more interesting and valuable returns to the student of our architecture and of library problems. The university libraries and that of the Wisconsin Historical Society in particular will repay the most careful examination.

It has been a decade of building, and the end is not yet. The New York Public Library's building now in process of erection is but the largest of scores either planned or under way. For most of this expansion Mr. Carnegie is responsible. There seems to be no limit to his generosity, and with very few exceptions, the money he has given

to libraries has gone into buildings. Mr. Carnegie is a firm believer in the doctrine that the public should support the public library, and he has regularly stipulated that ten per cent. of the amount which he gives for a building should be pledged by the community as an annual appropriation for maintenance. His gifts have gone both to cities already possessing libraries great and small, and to others where libraries must needs be organized to take advantage of his gifts. Exactly what the results of his munificence, aside from the buildings, will prove, it is too early to say. There seems to be very little likelihood of any but good consequences resulting from his wholesale giving.

So much for the 'bricks and mortar.' On the side of library science substantial progress has been achieved. The spirit of cooperation between libraries was never so strong as at present. That spirit which produced 'Poole's Index' has resulted in the current indexing of over two hundred serials of a technical sort in addition to a continuation of this earlier work on the more popular magazines. Far more important than any other feature of the decade has been the adoption of uniform rules for cataloguing by many of the libraries of the country, for the purpose of securing printed catalogue cards from a central bureau. The master minds among librarians since the middle of the nineteenth century have been urging that it was folly for each individual library to reproduce for itself, after the fashion of the middle ages, manuscript catalogue entries for current printed books. A printed book should be catalogued on a printed card which could be bought either with, or at the same time as, the book. So ran the preaching of the idealists. The American Library Association for a time endeavored to do this through its publishing board; later a commercial organization took the work from the hands of the association and continued it for a short time. Both finally dropped the scheme as financially unprofitable. It was reserved for the Library of Congress to take the first effective step toward emancipating the library profession from the ancient bondage of the scribe. First by a series of compromises the libraries of the country, through a committee of their association, adopted a new set of rules for cataloguing. Then the Library of Congress announced that it was ready to sell the printed cards which it makes for copyright books, its other accessions, and such books as it re-catalogues, at the regular price of government publications, *i. e.,* the cost plus ten per cent. This is now being done with great benefit to all concerned. The result has undoubtedly been disappointing to some enthusiasts who had confidently expected that henceforth their catalogues would make themselves. But while the labor of cataloguing has by no means been completely eliminated, the result attained by the use of this printed card is a far finer, fuller and

more perfect card index than any one library could ordinarily afford to make, and that at a cost much less than that of manuscript cards. There is every reason to look forward not alone to a great extension of the present work of supplying printed cards to scholars, bibliographers and libraries, but also to an extension of the scheme in the direction of international exchange or purchase of printed catalogue cards. The beginnings of such a movement are to be seen in the bibliographical labors of the Institute Internationale of Brussels and the Concilium Bibliographicum of Zurich, while the International Catalogue of Scientific Literature for which the Royal Society of London is sponsor is another great step toward international cooperative cataloguing.

Bibliography has received a great impetus in the past decade in America. Among other signs is the inevitable one of an organization. Americans, said Agassiz, when they have anything to do, must have a president, vice-presidents, secretary, treasurer and a constitution. The genial Swiss was right. The Bibliographical Society of Chicago is about to become the American Bibliographical Society. Meantime private and corporate activity has produced some noteworthy bibliographies, of which The American Library Association's 'Guide to the Literature of American History,' Mr. Evans's 'American Bibliography,' the 'United States Catalogue of Books in Print' and the 'American Catalogue' are perhaps the most remarkable. The list might be indefinitely extended. Bibliography, whether seen in the form of the scholarly treatise, such as the catalogue of the Dante collection of Cornell University, or in that of the latest reading list for children, has become a distinct feature of library progress in America.

There has been no small amount of legislation affecting libraries in the period we are considering. This has taken, as a rule, two directions, first, that of laws creating or amending a general act providing for the establishment of libraries, and second, laws establishing library commissions in the several states. The latter feature is the most prominent in the history of the relation of the state to libraries. In 1893 Massachusetts, New Hampshire and Connecticut alone possessed these boards. Now twenty states have established them by statute. Generally these commissions are composed of certain state officials *ex officio* (usually the librarian of the state library and the state superintendent of public instruction) and certain public-spirited citizens who serve without pay. They have a modest sum to be expended in employing inspectors and organizers. In general their work has been limited to helpful suggestion to the libraries of their states, and to the administration of a system of traveling libraries, another new development of the decade. In certain states the commission is empowered to render some small financial support from state funds to

public libraries. The Wisconsin commission has furnished the model which has generally been followed in the west, while the Massachusetts commission has been the type for the eastern states. The western commissions have had somewhat more legal authority, as well as larger sums to expend, and have usually employed more officers than have those in the east. The future will doubtless see an extension of this benevolent state supervision and help. It must be confessed that no other influence has been so potent in the improvement of the condition and administration of the smaller and more backward libraries as these commissions. They have fully justified their right to exist. They have also furthered to a remarkable extent the creation of new libraries in communities not previously possessing them. 'Traveling libraries,' small collections of some fifty books, have been called into being and managed largely through the commissions. These small collections are sent to rural communities, and even to places in large cities where they are desired, are kept for a few weeks, and exchanged for another set. They have commended themselves most highly to those interested in bringing books to people who have few or none.

This leads us naturally to a consideration of what may be termed the missionary spirit in library work. It may be remarked in passing that this seems a peculiarly American development, and that in general a growing consciousness of the possibilities a high and useful service in the life of the municipality has been one of the conspicuous features of the public library movement. The librarian who regards himself as a missionary of the book has been much in evidence of late, and on the whole has been both efficient and sane. The idea that he is a custodian of books merely has ceased in large measure to be the librarian's conception of his office. He is rather a guide and helper to the use of books. "The best that can be said for any book in this library," said an enthusiastic leader in this sort of work, "is that it is entirely worn out, and we must buy two new copies of it." This was in answer to the faint protest of an elder librarian to the effect that children should not be allowed in libraries because they wore out the books by reading them so much. This zeal for helping others to books, to the right books, has resulted in many reforms in the internal arrangement of library buildings and in the relations of the administration to the public. As a rule, the newer libraries are allowing a great amount of freedom in direct access to the shelves on the part of all users of the library. Many of the more recent buildings have been planned so that the visitor may go directly to the shelves, and many of the older buildings have been remodeled to permit this practise. In almost every way this has been a gain. There has come with it no small loss of books, but that loss is insignificant in view of the greatly increased use of the libraries which has resulted from easy personal contact with

books. Most libraries in the future will undoubtedly be planned to permit direct access to open shelves for a great part of their collections. There is, however, a point where this privilege ceases to be of use to the public and to the library, and this fact is now very generally recognized.

Open shelves are but one manifestation of the missionary spirit. Special rooms for children in charge of specially trained assistants are another result of this desire to bring books and people together. The creation of 'children's rooms' has been on the whole a great blessing to libraries. It has drawn away the younger children from the reading rooms and delivery counters, and has perhaps ingrained the reading habit in very many little ones. Certainly the children's room with its cheerful and prettily decorated walls, its low tables and chairs and its tactful, kind, experienced director has proved a boon to countless children into whose homes none of these delectable things enter. This particular form of library work is, however, as yet too young to enable us to judge of its ultimate results.

Another form which the missionary spirit has taken is a closer relation and a more effective cooperation between libraries and schools. The desire for an organization to give opportunity for the public exploitation of this sort of work produced in 1896 the Library Section of the National Educational Association. Not the schools alone, but women's clubs and social settlements, and, in general, all organizations whose members use books in their work, have been brought into friendly relations with the progressive libraries. In short we may safely affirm that public libraries are studying the needs of their communities as never before, and that the somewhat vague notion of aiding the 'public' is fast being replaced by concrete and tangible assistance to organizations and individuals.

The libraries in the large cities have been showing a most decided desire to assist their clients in securing books. To this end the branch library and the delivery station have experienced an almost marvelous development in the past decade. There is hardly a public circulating library of prominence in the country which does not maintain from half a dozen to half a hundred reading-rooms with small collections of reference books, as well as numerous stations for delivery of books from the central library. The largest number of these branch libraries will ultimately be found in New York, where Mr. Carnegie's gifts provide for eighty of these smaller centers in the greater city. Branch libraries have not infrequently been established at the request of large manufacturers or other employers of labor near their places of business, and in some cases the running expenses have been paid by them.

Among librarians also the spirit of mutual helpfulness which has been so characteristic a feature of the library movement in this country

has grown greatly. Library clubs, state associations, interstate conferences and the American Library Association have all grown in membership, while their number has increased threefold at least. Two new schools for training librarians have been established in the past decade, and the older schools have strengthened their curricula and raised their standard for admission. One new journal devoted particularly to the work of public libraries has come into existence.

Any summary of this decade would be incomplete which failed to mention the great additions to American libraries in the shape of special collections or endowments for special purposes. Such gifts as the John Carter Brown Library of Brown University, the Riant collection at Harvard, the Yale collection of Semitic manuscripts, the Dante collection presented to Cornell by Willard Fiske, the Avery Architectural Library at Columbia, the Morgan collection of Vergils and the Garrett collection of Arabic manuscripts at Princeton, and the Ford and other collections of the New York Public Library, are but conspicuous examples of the collector's generosity which has been so prominent a part of recent library history. The man of wealth may easily give money for a building, but the scholarly collector who turns over to a library for keeping and use the result of his efforts of years gives perhaps even more munificently. The libraries of this country are yearly receiving such donations in ever increasing numbers.

It would be a rare and happy fate were the librarians of America able to remind themselves of no great losses from their ranks in the past decade. Such is, unfortunately, not the case. Three of the pioneers in library progress have died during this period. Those who know intimately the history of the library movement will at once acknowledge that in the loss of Wm. F. Poole, Justin Winsor and C. A. Cutter the library world has been sorely stricken. Dr. Poole is remembered by historians and librarians alike for his services to American history and bibliography. Mr. Winsor's achievements as a cartographer, historian and librarian are too well known to need more than mention. Mr. Cutter, whose death occurred only last summer, was not so widely known outside the circle of technical workers. To librarians he was celebrated for a long series of most valuable contributions to the problems of classification and cataloguing, while his personal qualities endeared him to all. That such men were to be found foremost among American librarians is one of the occasions for pride in their calling. Their memory should prove one of the greatest incentives to future workers in their chosen field.

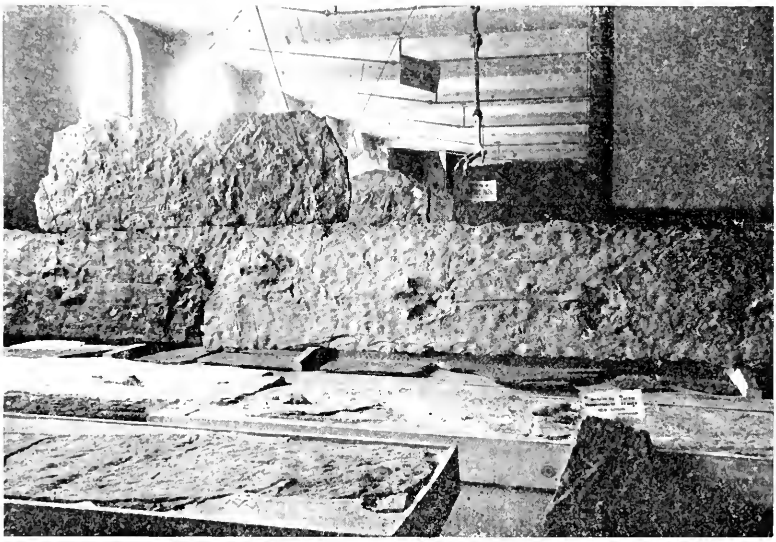
It would be a rash man who should venture to predict the directions of library growth in the next ten years. Certain tendencies, however, may be inferred from the immediate past. It is almost certain that the impetus given to public libraries by Mr. Carnegie will

result in steady growth and an increased efficiency in this field. It is equally certain, I think, that more efficient and widely extended state inspection and advice to libraries are likely to be had in the near future. Library legislation is tending to become more uniform in the several states, and perhaps the enabling acts which now permit public libraries to be supported by taxation may be exchanged for mandatory acts compelling their establishment after the manner of public schools. The greatest internal improvements which can be foreshadowed will probably be the growth of a scholarly spirit among librarians, and an increased emphasis on bibliographical work. A large measure of cooperation in the technical details of library administration and the consequent cheapening of its cost may also confidently be expected. Finally, it is entirely probable that the educational value of libraries in the community will come to be greater both by reason of the conscious efforts of the librarians to increase their efficiency, and by the recognition of those efforts on the part of the public whom they serve.

NATURE'S HIEROGLYPHICS.

BY DR. RICHARD S. LULL,
MASSACHUSETTS AGRICULTURAL COLLEGE, AMHERST, MASS.

ONE of the loveliest parts of all New England is the broad valley of the Connecticut River, of deep human interest because of its having been the theater of many of the conflicts during the struggle for existence between the white settlers and the aborigines, and occasionally one comes across a monument whose inscription tells of the fierce engagements of colonial days. More numerous still are the records of an earlier race, not in this instance of mankind, but of creatures far antedating man in antiquity, which have left involuntary inscriptions on the rocks.



PART OF THE AMHERST COLLEGE MUSEUM.
The long slab shows six successive tracks of a tail-dragging carnivorous dinosaur.

For nearly a century these impressions have been observed by the good folk of the valley, though as many of them had to the uncritical eye the familiar appearance of bird tracks, they were considered as such, and to those who were unaware of their vast antiquity they were undoubtedly of little interest. As soon, however, as they became known to men who could appreciate their full significance, the impressions were at once recognized as being of great scientific interest, and it is to the efforts of the late President Edward Hitchcock, of Amherst College,

that we owe the founding and development of a study which soon rose to the dignity of a science. The interest of President Hitchcock ceased only with his death in 1865, and his tireless energy resulted in the bringing together of a magnificent collection of track-bearing slabs and in the description and publication of more than one hundred species of track-making organisms.

The impressions, while mainly of footprints, also give evidence of dragging tails and other portions of the body or of the armoring and texture of the skin. Other attendant phenomena have left their records also, such as the rainprints of a summer shower, ripple and other beach marks, and the shrinkage cracks which are found in sun-dried mud. These are preserved with wonderful fidelity and minuteness of detail.

Classification of the Tracks.

The footprints may be classified under three groups, according to the mode of progression or the posture of the maker. First the impressions of true bipeds, those whose very bird-like imprints gave the popular name of bird tracks to the phenomena as a whole. Here may be, though rarely, the trace of a dragging tail, but with this exception the hind feet alone leave their record on the rocks.

The second group is as truly bipedal as the first in gait, and the footprint is usually as bird-like as before, but there may occur in addition to an occasional tail trace the impressions of little five-fingered hands placed just in front of those of the feet, while from the rear of the footprint often extends that of a long slender heel. These impressions of the hand and heel were only formed when the creature rested, for, except for differences in shape, the footprint of the moving form can not be distinguished from those of the first group.

The third are the true quadrupeds, not alone in resting posture, but during locomotion as well, in some cases with feet whose impressions are full of character, which gives some clue to their maker's affinities; others slender toed and obscure, whose true relationship with known creatures it is difficult to conjecture.

There remains yet a fourth group of imprints, which, while evidently formed by living organisms, are certainly not those of vertebrates or backboned animals, and, if one may judge from their appearance, may have been made by creeping worms or by crab- or centipede-like creatures or possibly by insects.

Interpretation of the Footprints.

Even to the layman the mounted skeleton of an extinct animal is something tangible which the imagination can readily clothe with flesh and endow with life; but the first impression which the mind receives of the footprints is like that of an ancient inscription whose characters

are those of an unknown tongue, the meaning of which is an enigma unless one has the key. The earlier students attempted to decipher the footprints by comparing them with animals then known, with the

RESTORATION OF THE NEW WINDSOR DINOSAUR.
The probable maker of the tracks on the Middletown slab.

result that they thought they recognized the impressions of batrachians, reptiles, birds and mammals; in fact every group of creatures which were

THE MIDDLETOWN SLAB COVERED WITH THE FOOTPRINTS OF CARNIVOROUS DINOSAURS.
The tracks are in high relief.

capable of making tracks. It will be seen at once that the only true key to these nature's hieroglyphics would be actual skeletal remains associated with the footprints or, if found elsewhere, in beds of equivalent age.

In 1818 the first fossil skeleton found in the valley was discovered at New Windsor, Conn., and later, just before the civil war, another was brought to light at Springfield, Mass. These, while fragmentary, were recognized to be reptilian in character, and when the latter specimen came to light it at once cast a grave doubt upon the correctness of the accepted interpretations. Hitchcock himself speaks of these remains as being 'those of fair representatives of the creatures which made the tracks.'

It was not until nearly the last decade of the nineteenth century that further excavations at New Windsor, which resulted in the finding of two more specimens, enabled Professor Marsh, of Yale University, to restore the creature and to give us an adequate knowledge of its organization and affinities and thus to furnish the first true key to the correct interpretation of the footprints. Further discoveries abroad, but more especially in our own great west, have given us a very complete knowledge of the magnificent race of reptiles to which the Connecticut Valley forms belong.

During the Mesozoic age, comparable to the medieval times in human history, reptiles were the dominant forms; they occupied the places in the economy of nature to-day taken by the birds and beasts, both animal and plant feeding, as well as by the whales and other denizens of the air, earth and sea; but among the great reptilian assemblage none were more varied in size, aspect and habits than the dinosaurs or terrible lizards, at that time the peers of the animal realm. These creatures are first known from the rocks of the Triassic, the earliest of the three periods into which the Mesozoic age is divided, reaching their millennium as a race during the close of the second or Jurassic period, at which time they attained their greatest profusion in numbers and their highest development in point of size. In the strata formed toward the close of the Cretaceous, or final period, the dinosaurs reach their maximum of specialization, developing forms among the most weird, grotesque, as well as the most terrifying, the world has ever known. This marks the decadence of the race, the prelude to its extinction, for in the immediately overlying rocks of the Tertiary period not the least vestige of a dinosaur has been found.

At least three great orders of Dinosauria are recognized, of which two, embracing the land forms, were represented in the footprint fauna, while of the third, gigantic quadrupeds, whose vast bulk has won for them the name of *Cetiosauria* or whale lizards, plant feeding and semi, if not wholly, aquatic in their habits, there is not a trace.

The remaining orders were sharply differentiated in their habits of feeding, the one being carnivorous, the other herbivorous, in diet; and while the more primitive members of both orders were quite similar, such is the influence of habit upon a race that their evolution

was a divergent one, the ultimate representatives differing widely from one another in bodily contour, form and structure of the teeth, and in mode of progression.

The Carnivorous Dinosaurs.

The earliest and most primitive of the carnivorous dinosaurs were those already alluded to as having been found at New Windsor and Springfield in the Connecticut valley. These creatures were somewhat lizard-like in general aspect, with the fore limbs fitted for grasping, while the much larger hind limbs, which were very bird-like, were used for locomotion. A study of the skeleton seems to indicate that the center of gravity came just about the region of the hip socket, so that the weight of the tail counterbalanced that of the forward portion of the body, thus making progression upon the hind limbs the only probable gait. The grasping hand, the structure of which is ill-fitted for locomotion, gives color to this assumption.

An extremely interesting slab in the Amherst College Museum, whose upper surface has been worn smooth by the feet of nearly two generations of men, for it did duty as a paving stone in the streets of Middletown, Connecticut, for more than fifty years, bears on its under surface in high relief numerous perfect tracks, in this instance not the footprints themselves, but the natural casts of the feet which made the prints, formed when the incoming tide deposited its load of sediment over the place where the creatures had walked. This *bas relief,* for such it may be called, admits of the following interpretation: that the makers of the tracks were true bipeds, as all of the casts are those of hind feet, moderately long of limb, walking with alternate steps, with compact bird-like feet, having three toes directed forward with moderately pointed claws, and evidently another directed backward whose claw only occasionally touched the ground. There is no sign of a caudal trace, showing that the tail if present was used only as a counterpoise. The size, length of limb, number and proportions of the toes, and the absence of hand and tail impressions, together with the fact that they are among the most numerous of the tracks, the makers of which would in consequence be among those most likely to be preserved as fossils, all point conclusively to the New Windsor dinosaur as the creature whose existence is thus recorded.

The carnivorous dinosaurs followed at least two lines of evolution, the more conservative of which simply increased in size and in consequent strength and ferocity throughout their racial career. In this group, perhaps the most remarkable feature is the constantly increasing disparity of size between the fore and hind limbs, for in the later forms the arms were so absurdly small that it is difficult to conjecture their use. As the fore limbs decreased in size, the hind legs, in addi-

tion to their duty of supporting their owner's weight, had to assume the grasping function as the hand relinquished it, and the claws became in consequence great talons, differing thus markedly from those of the earlier types.

One seems, therefore, justified in interpreting a second group of tracks, much larger than those of the Middletown slab, sharp clawed and with a very narrow sinuous tail trace, as having been made by a dinosaur of this group. If one should picture an animal about twenty feet in length, weighty in build, with talon-like hind claws, and therefore with small fore limbs and with a fairly erect posture so that the tip of the rather short heavy tail touched the ground, one would have a fair notion of this the maximum form, both in size and in degree of specialization of the Connecticut valley carnivores.

The other group of carnivorous dinosaurs were of a very different sort, always retaining their agility and the grasping power of their fore limbs, but not increasing very materially in bulk. A beautiful example of this race from the Jurassic beds of Wyoming has recently been mounted at the American Museum of Natural History, New York, and has been given the name of *Ornitholestes,* the bird robber, in allusion to its supposed habits. It is a slender animal with an extremely long tail. The hind limbs are fitted for locomotion *par excellence,* while the fore limbs are more slender with but three very long fingers in the hand, admirable for grasping elusive prey.

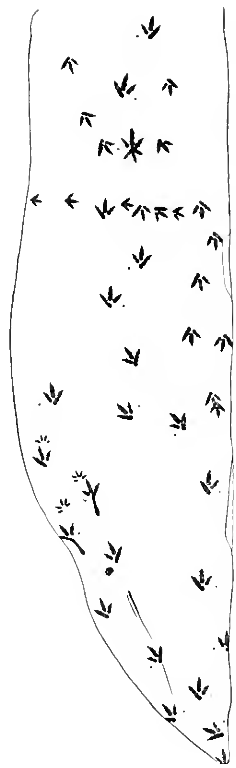
In studying the footprint slabs one frequently comes across some very small impressions, hardly exceeding three inches in length, three-toed, with no indication of a grasping claw behind, nor of a tail trace. One might be apt to attribute these little footprints to the young of the larger species until one notices the great interval between the successive tracks, a distance six to eight times the length of the foot itself. This of course gives evidence of extremely long limbs, so that the name of *Grallator*, he who walks upon stilts, which has been given to this group, is not inapt. While no skeletons are known from the same horizon with which the footprint may be compared, it seems safe to consider it one of these aberrant carnivores, of very slender build, agile, and of habits possibly similar to those of the wading birds.

It is but just to the earlier naturalists to say that we have no absolute proof that *Grallator* was not a true bird, but that it was seems doubtful, as the foot agrees in structure with that of known dinosaurs, and birds are totally unknown from so remote a period.

Herbivorous Dinosaurs.

Plant feeding dinosaurs are known by their skeletal remains only from the Jurassic and Cretaceous periods, but that they existed during the earlier Triassic seems indubitably certain from the fact that their

Herbivorous Dinosaurs of Primitive Type restored from the Data furnished by their Footprints.



Footprints of an Herbivorous Dinosaur showing where the Animal rested.
Drawn from a slab in the Amherst College Museum.

wide variation and distribution in the Jurassic implies an ancestry in the earlier period, and also that their footprints on the Triassic sandstones are unmistakable.

The more primitive herbivores resemble their carnivorous allies in general contour and in mode of progression, though differing in certain internal characters and in the teeth, these being necessarily changed to enable their owner to chop or grind up the plants upon which it lived. The rear part of the jaws became, in the later forms, veritable magazines of teeth, the latter replacing one another in vertical succes-

Beach with Tide Mark and the Tracks of an Herbivorous Dinosaur going down toward the Water.
Photographed from a slab in the Amherst College Museum.

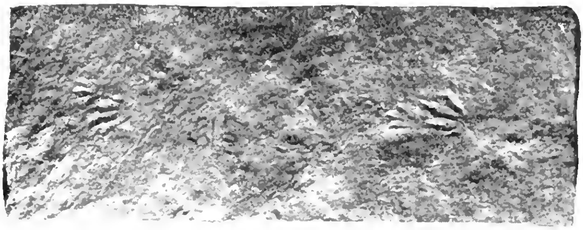
sion, a new one being always ready to take the place of one lost or worn out in service. The front part of the mouth bore a few teeth in the earlier types, but these soon gave way to a horny upper and lower beak, turtle-like in aspect, probably used for cropping succulent herbage.

The hind feet were still very bird-like, especially in the less specialized forms, but with blunted claws, while the hand always retained its five fingered condition with short rounded nails. The fore limbs could always be used for the support of the forward parts of the body, though perhaps not always for food gathering. It is extremely doubtful whether any of the earlier plant feeders ever walked on all fours, though in the later forms, owing to the great weight of armament which they carried, a four-footed gait was rendered necessary. The herbivorous dinosaurs proved a more plastic race than their carnivorous brethren, and towards the close of their career there arose among them the remarkable types, already alluded to, which marked the decadence of the group.

In the footprint fauna the herbivores were all true bipeds, but did occasionally impress the hand, including thus all the footprints of the second or occasionally quadrupedal group, and probably some of the first as well, though this is open to question.

The footprints give us thus our first recorded evidence of herbivorous dinosaurs in the Triassic, which will some day probably be verified by the finding of their bones.

One extremely interesting specimen in the Amherst collection bears in all about fifty impressions, most of them made either by the same animal walking back and forth along the beach or by several of approximately the same size. In one of his journeys the creature slows down as shown by the fact that the tail begins to drag, whereas it had been



FOOTPRINTS OF A SMALL QUADRUPEDAL REPTILE, *Stegomus*, WHOSE RESTORATION IS SHOWN.

held out stiffly behind to counterbalance the weight of the body. Then the animal stops and comes down on all fours impressing the little hands and long heels, then, having satisfied its purpose, it rises again to its hind feet, touching one hand and the tail tip once more to the ground in regaining its balance, and then goes on its way. This single slab gives us thus a knowledge of the creature's size, proportions, gait, resting posture, feeding habits, for the little hand with its nail-like claws could never have been used for grasping prey, and finally of the texture of the skin on the soles of the feet with creases between the joints, like those of the human fingers, and tiny granulations, like

RESTORATION OF *Stegomus*, A DISTANT ALLY OF THE MODERN CROCODILES BUT WITH HIGH STILTED LIMBS.

mustard seed covering the entire surface. Footprints of this character are very common and indicate dinosaurs of rather light build, ranging in size from three and a half to seven feet.

One of the most remarkable of all of the footprints measures twenty inches in length, with four toes directed forward bearing broad rounded claws. The foot was bear-like, in that the entire sole and heel rested upon the ground and bore around its margin a broad web-like flange of skin, the probable function of which was to prevent the creature

from sinking too deeply in the soft mud. The hand very rarely impresses, and but one instance is known of a dragging tail. What this uncouth brute looked like, one can not even imagine, for no skeletal remains are known which it in the least resembles.

One very numerous group of large bird-like tracks unaccompanied by hand or tail impressions seems from the blunted claws to have been those of plant feeders, but of this we can not be sure, for the condor of the Andes is also blunt clawed, and suggests the possibility that the makers of these tracks may also have been carrion feeding, which would place them among the carnivores. Certain it is that they were dinosaurs, and among the largest of the valley forms, though probably but half the bulk of their successors in the later rocks. One huge footprint from Northampton, Mass., measures twenty inches in length and holds four quarts of water.

Quadrupeds.

There must have been quite a host of quadrupedal forms in the Triassic days, mainly of small size, but while they were probably of amphibian or reptilian origin nothing was really known of them until very recently. Professor Marsh found, some years ago, the remains of one animal, but unfortunately only the impression of the armor of the back remained, and, as the limbs were lacking, nothing could be learned of its probable footprints. A second specimen has just been brought to light, found in the village of Longmeadow, Mass., sufficient of which is preserved to show that the creature was long of limb and was probably a rapid runner. From its size and proportions, it corresponds very closely with one of the most numerous of the quadrupedal tracks. The Longmeadow specimen belongs to a group of primitive crocodile-like reptiles, to which Professor Huxley has given the name of *Parasuchia*. The footprints are small, but with a long interval between the successive tracks, with sharp claws, with four toes on the foot and five on the much smaller hand. Thus far only may we interpret the quadrupedal footprints with any assurance, for beyond this we are in the realm of almost pure conjecture, which in footprint interpretation has thus far nearly always proved wrong.

To summarize briefly, the footprint fauna contains amphibians, reptiles, and possibly birds; of the first we as yet know nothing, but we may be reasonably sure that they occurred; of the reptiles we have identified numerous dinosaurs, representatives of both great land-inhabiting orders, and we have also found indications of early crocodile-like forms. Other reptilian orders were doubtless present, but what they were we have as yet no means of knowing. Finally the only creatures which could have been birds could as readily have been dinosaurs and such in all probability they were.

Occurrence and Means of Preservation.

Fossil footprints have been found in various parts of the world, as in England, Germany, France, and, in our own country, in the Grand Cañon of the Colorado, as well as in association with Jurassic dinosaurs in the northwest; but it is in the valley of the Connecticut and in rocks of the same formation in New Jersey that they occur in an abundance and perfection of preservation which is unrivaled elsewhere.

In this region sandstone beds of great thickness occur which every now and then exhibit impressions with generally something of an interval between the track-bearing layers.

Geologists have been led to suppose that the broad valley of the Connecticut was during Triassic times a tidal estuary extending from the village of Northfield, Mass., to New Haven, a distance of one hundred and ten miles, with an average width of twenty miles. In places in this estuary were mud flats, some well out in the ancient bay, others nearer the shore, which were left bare by the receding tides. Here the animals loved to congregate, possibly they came for food, but it seems more likely that the dinosaurs here assembled at certain seasons for mating as the seals do in the Alaskan rookeries.

The means of preservation were threefold, of which the first was the fierce heat of a tropical sun, for plant remains indicate that such climatic conditions prevailed, while the second and third are really attributable to one cause, volcanic activity. This resulted in the formation of the Holyoke and Mt. Tom ranges and in broad lava flows. Upon these sheets the sand and silt were deposited, forming thus the tidal flats where the creatures congregated. The heat of the cooling lava added its baking effect to that of the sun, while the decomposing lava liberated an iron cement which completed the task of solidifying the overlying material into rock.

The impressions made when the tide had ebbed were thus somewhat hardened before the incoming flood bearing its burden of sediment gently buried the traces without the least injury, thus preserving for our enlightenment these monuments of the past.

THE PRESENT PROBLEMS OF PHYSIOLOGICAL CHEMISTRY.*

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IN considering a proper presentation of the subject assigned me, I am impressed with the influence which a man's own field of work and his own line of thought will naturally exercise upon his point of view. It may be questioned whether his judgment can be wholly trusted, whether he will not, in fact, unconsciously it may be, give a dwarfed or one-sided presentation of the subject from a natural habit of looking at things in their bearing upon the line of work and thought in which he himself is personally most interested. While this may not be wholly undesirable, still of greater advantage will be a brief but judicious presentation of all the more important problems that confront the physiological chemist of the present day, but whether this can be done satisfactorily in the time allotted is very questionable. However, the effort will be made to emphasize, so far as the time will allow, what to the writer seem the more significant and far-reaching problems in physiological chemistry that call for speedy solution.

Of fundamental importance is the question, what is the exact chemical constitution of proteid matter? The basis of all cell life, the most complex molecule that enters into the structure of the living organism, proteid or albuminous material holds a peculiar position. A labile molecule, it is easily prone to change, and its many decomposition products confront us on all sides in our study of life's processes. Yet to-day, in spite of all that has been accomplished, even with the brilliant work of Kossel and Emil Fischer, we still lack adequate knowledge of all the groups and radicles that are combined in this atomic complex.

In the study of metabolism and nutrition, both in health and in disease, in our conception of the anabolic processes of life, in our theories regarding the chemical relationships of the varied katabolites floating about through the organism and in many other connections, we need for our guidance a full knowledge of the chemical nature of this most important class of substances. Thanks to the work of many brilliant investigators, our knowledge is progressing and broadening, but we still lack that comprehensive understanding of the inner struc-

* Read before the Section of Physiological Chemistry in the International Congress of Arts and Science held at St. Louis, September 22, 1904.

ture of the molecule that would serve to illuminate our field of vision and give us a clear conception of the chemical constitution of this group of physiologically important ground substances in living protoplasm.

As is well known, the proteid bodies constitute a group of widely divergent substances. Of these, the basic protamines are undoubtedly the simplest and lowest in the scale, and it is quite probable, as suggested by Kossel, that these substances constitute the nuclei of all proteids. The protamines differ somewhat among themselves, but as a group they are characterized by their high content of diamino-acids, especially arginin. Thus, salmin yields on decomposition 84 per cent. of arginin, clupein 82 per cent., cyclopterin 62 per cent., and sturin 58 per cent.* Sturin also contains 13 per cent. of histidin and 12 per cent. of lysin, while the other protamines appear to contain no diamino-acids aside from arginin. Further, the protamines contain diamido-valerianic acid, monoamido-valerianic acid, tyrosin or p-oxyphenyl-amidopropionic acid, skatolaminoacetic acid, a-pyrrolidinecarbonic acid and serin.† Salmin‡ has also been shown to contain alanin, leucin, probably also phenylalanin and aspartic acid.

If we pass from the simplest of the proteid bodies to the most complex, as the nucleins, we find present in the latter not only arginin, lysin and histidin, but, in addition, such bodies as thymin, the purin bases, leucin, aspartic and glutamic acids, two sulphur-containing groups, furfurol-forming groups, pyrrolidinecarbonic acid, a skatol-forming group, phosphoric acid, amidovalerianic acid, a levulinic acid-forming group, glycosamine, pentose, uracil and probably phenylamido-propionic acid.§ In the histon from the nucleohiston of the thymus, we find in addition to the hexone bases and the monoamido-acids characteristic of the ordinary albuminous bodies such substances as glycocoll, cystin and alanin.

These statements, brief and incomplete though they are, will serve to illustrate the complexity of the proteid molecule, and at the same time they indicate the close genetic relationship which unquestionably exists between the varied members of this large group of substances. There is no doubt that Kossel and his co-workers in their efforts to unravel the constitution of the protamines are pursuing a wise course in paving the way for a comprehension of the exact nature of the more complicated proteids. There is no doubt that the protamines of one

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* Kossel and his students. See Kossel and Dakin, 'Ueber Salmin und Clupein,' *Zeitschrift für physiologische Chemie*, Band 41, p. 407.

† Kossel und Dakin, 'Beiträge zum System der einfachsten Eiweisskörper,' *Zeitschrift für physiologische Chemie*, Band 40, p. 565.

‡ Abderhalden, 'Die Monoaminosäuren des Salmins,' *Zeitschrift für physiologische Chemie*, Band 41, p. 55.

§ See Kossel, 'Ueber den gegenwärtigen Stand der Eiweiss Chemie,' *Berichte der Deutschen Chem. Gesellschaft*, Jahrgang 34, p. 3214.

type or another are integral parts of every proteid molecule, and when their chemical constitution is made quite clear, much will have been accomplished toward a fuller understanding of the more complicated forms.

It needs no imagination to foresee what a full knowledge of the chemical constitution of all types of proteid matter will mean for the physiologist and physiological chemist. Much that is now cloudy and uncertain in our understanding of cell and tissue metabolism, in our comprehension of nutritive changes in general, of digestive proteolysis and of intracellular autolysis, will become clear as crystal. The problem, however, is not a simple one, but is exceedingly complex, for it is to be remembered that just as the individual proteids differ from each other in superficial reactions and characteristics, so do they undoubtedly differ in their inner structure. Hence, we must expect to find variations in the make-up of the individual molecules, and it is one of the most important problems of to-day to ascertain the nature of these chemical variations, to recognize the individual groups that give character to the molecules and to learn how these groups are bound together to make the typical proteid of this and that tissue or organ. The solution of this problem promises much for the advancement of physiological chemistry, but it holds out the promise of even more for the good of physiology in general, since there is bound up in the chemical structure of the proteid molecules a full and complete explanation of tissue changes, and of many metabolic phenomena which to-day are as sealed volumes.

The development of our knowledge regarding the cell as a physiological unit has led to a fuller recognition of the importance of discriminating between the primary and secondary cell constituents. As a result, the physiological chemist has come to realize the necessity of more exact knowledge as to the nature and distribution of the primary components of cells, because of the bearing this knowledge may have upon the general question of how far the lines of chemical decomposition characteristic of each group of cells are dependent upon the character of the anabolic processes by which that particular cell protoplasm is formed, and how far the peculiar katabolic or retrogressive changes of that group of cells are due to outside influences, exerted by specific nerve fibers, or by the character of the blood and lymph stream. The physiological chemist would know whether the secret of glandular secretion, of tissue changes, of metabolic activity, is to be found in the particular forms of protoplasm that enter into the structure of the component cells, whether it is associated in any way with some inherent quality of the primary cell constituents.

There is something marvelous in the unerring certainty with which a given group of cells performs its work, never deviating a hair's breadth

from the beaten course, and turning out year after year a definite line of products for the specific purpose in view. Why is it that the epithelial cells of the salivary glands always manufacture mucinogen and ptyalin; the gastric gland cells pepsinogen, renninogen and hydrochloric acid; the cells of the pancreas trypsinogen and steapsin; the hepatic cells bilirubin, biliverdin and the specific bile acids; the cells of the thyroid iodothyrin, and the cells of the adrenals epinephrin? Essentially the same blood and lymph bathe all these cells with a like nutritive pabulum, and yet each group of cells performs its own line of work, never going astray, in health, and never even temporarily producing a product which rightfully belongs to the other class of cells. Are we to suppose that all these varied products are manufactured from the same cell protoplasm, from a common stock, that each one owes its origin to some particular force controlled by extra-cellular influences, each group of cells being made to manufacture a given product out of the same mother substance? Or, on the other hand, are we to assume that each group of cells, as it is developed, has as a birthright the quality of producing from its particular protoplasm a certain line of products, simply because of the peculiar chemical nature or constitution of that protoplasm?

In other words, do all the intricacies of cellular activity depend primarily upon the character of the anabolic processes by which that protoplasm is built up out of the food materials by which the cells are nourished? It may be just as difficult to explain why and how the cells are able to manufacture a specific protoplasm out of a common pabulum, but the main problem which confronts us is surely capable of being solved. We need to know how far the primary cell constituents of different groups of cells, of the different organs and tissues are similar or unlike each other. If it is shown that the primary cell constituents differ for each glandular organ and tissue, that each group of individualized cells has a protoplasm characterized by some specific feature, then we shall have reason to believe that the anabolic processes are as much, if not more, responsible for individuality of function than the katabolic processes. We may conceive of all protoplasm being built, so to speak, on a certain general plan of structure, but with side chains of varying nature, and that these side chains determine in a measure the character of the katabolic or alteration products that result from the natural activity of the cell protoplasm. In other words, if this conception be true, it is the chemical constitution of the cell protoplasm that is primarily responsible for the character of the changes that take place in all active tissues and organs. The extent of oxygenation as influenced by the circulating blood, the direct and indirect influence of various nerve fibers, etc., may all act as modifying agents, but only to the degree of accelerating or inhibiting the rhythmical process which

travels along a certain definite channel because of the peculiar chemical nature of the cell protoplasm. Once started, the process of katabolism takes a definite course, with formation invariably of the same products, because that particular cell protoplasm, owing to its peculiar make-up, tends to break down along certain definite lines of cleavage, as it were, and so the products split off are always the same.

We already have considerable knowledge which tends to indicate that the cells of individual organs and tissues have a certain individuality as regards their primary components, notably in the nucleoproteids present, but our knowledge is by no means complete enough to permit of broad generalization. The problem is an interesting one, and permits of a definite answer by the application of thorough and persistent investigation.

As an allied question, more or less in harmony with what has just been said, reference may be made to the part which ferments and enzymes possibly play in initiating and carrying forward tissue changes, as well as the metabolic changes that occur in glandular organs. Ferments have come into such prominence of late years as responsible agents for so many transformations, that we may well query whether their influence does not extend far beyond the limits originally assigned to their field of activity. The discovery of oxidases and the part which these agents may play in tissue changes, the undoubted existence of ferments in such glands as the thymus, suprarenal, spleen, etc., by which the recently studied autolytic changes in these glands are produced, raise the question whether ferments or enzymes are not far more largely responsible for the many transformations that take place in active tissues than has been hitherto supposed. Consider for a moment the peculiar products which result from the self-digestion (autolysis) of many of the glands so far studied. Note how the nucleoproteid of the thymus, for example, breaks down, yielding xanthin and a little hypoxanthin, together with uracil, but no guanin, adenin or thymin.* How the adrenal nucleoproteid likewise yields by autolysis considerable xanthin, but only traces at the most of the other alloxuric bases (Jones). By the self-digestion of the spleen, guanin as well as hypoxanthin is conspicuous, but it is a noticeable fact that in the autolysis of the thymus, for example, there is no appreciable amount of leucin to be detected, thus indicating that the above autolytic changes are not due to any ordinary proteolytic enzyme, but to some peculiar enzyme which acts directly and solely upon the nucleoproteids, splitting off certain of the contained alloxuric groups. In harmony with this view, Jones has just announced the presence in the pancreas, thymus and adrenals, of an enzyme to which he gives the name of guanase, which has the power of transforming guanin into xanthin. The same

* Jones, 'Ueber die Selbstverdauung von Nucleoproteiden,' *Zeitschrift für physiologische Chemie*, Band 42, p. 35.

investigator also claims the presence in the spleen of a related enzyme, called adenase, which transforms adenin into hypoxanthin. The inference is that in many glands and tissues there are specific enzymes, as yet undiscovered, which may be responsible for at least some of the transformations known to occur there.

That autolysis may be a possible explanation of the process of animal metabolism has been suggested by Levene* and also by Wells.† It has been clearly indicated by such able workers as Salkowski, Jacoby and others, that practically all animal cells contain within themselves ferments or enzymes that are capable, under suitable conditions, of digesting or breaking down the cell contents by a process similar to ordinary proteolysis, and it may perhaps be assumed that all active cells carry forward their ordinary metabolic processes by the agency of these intra-cellular ferments. Moreover, it is not inconceivable that ferments or enzymes of several kinds may exist side by side in a given group of cells, just as they are known to exist in the pancreas, by which we might infer the possibility of a series of transformations taking place at essentially the same time, through the harmonious action of a row of enzymes physiologically quite distinct.

Further, the recently discovered reversible action of enzymes, on which we have at command so much valuable work, suggests the possibility of a maintenance of cell equilibrium through this peculiarity of action, thus affording a tangible explanation of the means by which intra-cellular nitrogenous or proteid equilibrium is maintained, the various cells of the body building up or breaking down the proteid matter of their own tissues as circumstances require. If these ideas are true, then our conception of ferment action must be considerably broadened, and we have before us the possibility of explaining many of the phenomena of tissue metabolism by the action and interaction of intra-cellular enzymes. This is a problem well worthy of broader study, with a view to the elucidation of the general laws that govern tissue changes in general. In this connection we also have suggested the possibility of interaction of another kind, viz., that interdependence of one tissue or gland upon another for the full development of its functional activity, as illustrated by the part played by the enterokinase of the intestinal glands in the development of an active trypsin from the zymogen of the pancreatic cells, and by the action of the internal secretion of the pancreas upon the inert constituents of the muscle to develop in the latter an active glycolytic enzyme. How far this general principle extends in the metabolic phenomena of the body is entirely problematical, but merits careful study. Here, then, we have an

* 'Die Endprodukte der Selbstverdauung tierischer Organe,' *Zeitschrift für physiologische Chemie*, Band 41, p. 393.

† 'On the Relation of Autolysis to Proteid Metabolism,' *Amer. Journal of Physiology*, Vol. 11, p. 351.

added field of inquiry, worthy of careful consideration, if we are to possess a clear understanding of nature's processes.

Between the animal and the vegetable cell certain sharp lines of distinction are frequently drawn. Physiologists are wont to believe that the processes characteristic of the cells of animal tissues and organs are essentially destructive, *i. e.,* that they are principally katabolic, while in vegetable tissues, on the other hand, constructive processes are very conspicuous. In no way is this better illustrated than in the prevalent opinions regarding the parts played by the two classes of cells in the metabolism of proteid matter. We are accustomed to think that all proteid matter has its primary origin in the synthetical power of the vegetable cell, aided by its contained chlorophyll and the beneficent action of the sun's rays. The animal cell, on the other hand, can merely transform and reconstruct the various proteids furnished by the vegetable world, being without power to manufacture proteid matter *de novo* out of the simple groups and radicles which the vegetable cell utilizes so rapidly. In ordinary proteid katabolism, the various nitrogenous decomposition products are presumably all converted into urea and allied substances adapted for excretion. If, however, there is reversible ferment or enzyme action in the animal body, why may there not also be power to utilize, in some measure at least, the crystalline nitrogenous bases and amido-acids so abundantly formed in trypsin proteolysis, for the construction of fresh proteid matter? One may well query, considering the vigor of the proteolytic action of the enzymes poured into the alimentary tract, whether all these nitrogenous waste products represent just so much lost energy in their production and a further loss of energy in their immediate excretion from the body. In harmony with the 'luxus consumption' theory we may assume wisdom and ultimate gain in this speedy decomposition of excessive proteid foods in the alimentary tract, but the argument is not very convincing. Why may not animal cells, or the animal body as a whole, build up proteid matter out of simple nitrogenous compounds analogous to the action of plant cells? Loewi* has indeed experimented in this direction and states that the biuret-free end-products resulting from the proteolysis of ordinary food albumin can be utilized by the animal body for the maintenance of nitrogenous equilibrium, etc., equally well with the common proteid food-stuffs. His conclusions, however, have been called in question by other investigators, notably by Lesser† whose experimental data failed to confirm the above conclusion.

The problem, however, is an exceedingly important one. If the animal body has no power of utilizing the varied nitrogenous com-

* 'Ueber Eiweissynthese im Thierkörper,' *Archiv für exper. Pharmakol. u. Pathol.*, Band 48, p. 303.

† 'Ueber Stoffwechselversuche mit den Endprodukten peptischer und tryptischer Eiweissverdauung,' *Zeitschr. für Biologie*, Band 45, p. 497.

pounds of simple constitution formed in the gastro-intestinal tract by the digestive enzymes; if there is a complete lack of ability to construct new proteid matter out of these simple decomposition products, then surely we must inquire what is the real purpose of their formation? It is true that, with the limitations of our present knowledge, it is difficult to see why if digestive proteolysis has for its sole object the conversion of the proteid foods into forms suitable for absorption there should be any considerable breaking down of proteid beyond the proteose or peptone stage, since the latter bodies would seem to be most easily adaptable for transformation into the proteids of blood, lymph and tissue. On the other hand, it is well known that the proteid of the food is possessed of a physiological and chemical nature quite different from that of the proteid in the blood and tissues of the feeding animal, and it is quite conceivable that a synthetical process might be essential—in some degree—for the manufacture of the specific proteids called for by the blood and tissues of that particular species or individual. The question is one that demands careful consideration and thorough investigation, for it touches upon a chapter in nutrition on which we have at present very little satisfactory or convincing knowledge.

In this connection we may call attention to another problem, somewhat far reaching, but suggested by one of the preceding paragraphs, viz., the possible physiological action of the many katabolites, or decomposition products resulting from tissue changes throughout the animal body. In vegetable tissues, many of the nitrogenous products common to these structures are endowed with marked physiological power, as witness the vegetable alkaloids and the non-nitrogenous bodies like salicin, digitalin, picrotoxin, etc. Years ago, physiologists recognized that some of these nitrogenous bodies present in animal tissues did have a distinctly toxic action when introduced directly into the circulation, and hence they were frequently called animal alkaloids, but our knowledge upon these points is exceedingly obscure and indefinite. When we take into consideration the large number of nitrogenous products formed and present in the various tissues and organs of the body, products of proteolysis and of tissue changes; when we consider how these products circulate through the organism, in blood and lymph; how they come in more or less immediate contact with the different cells of the body prior to their decomposition or elimination, we can not avoid being impressed with the part they may play in stimulating and modifying tissue or other changes.

The significance of this suggestion is made all the more potent by the knowledge recently acquired concerning several of the internal secretions of the body and the powerful physiological influence exerted by their components. Where can be found a more active physiological agent than the blood-pressure raising constituent of the adrenals, the

epinephrin? Where is there a more active agent in modifying the nutritional processes of the body than the iodine-containing constituent of the thyroid, the iodothyrin. These may truly be counted as representing a type of substances manufactured or secreted primarily for the physiological effect they are capable of exerting; but what about the host of other substances present in the body, many of them simple products of katabolism? May they not have some marked physiological property that if known would serve a sufficient excuse for their formation? Or, may they not possess some hidden or obscure property which if once understood would make clear a secondary or subsidiary function of no small import for the maintenance of physiological equilibrium, or for the welfare of the body? Many suggestions and some facts present themselves, illustrating how direct and indirect influences may be exerted, all pointing toward the harmonious action and interdependence in function of many of the substances formed in the body. Some, however, undoubtedly have more or less of a toxic action, especially when formed in excessive or undue amounts. Thus, the alloxuric bases seemingly cause fever when injected into the circulation or taken per os,* and according to the recent observations of Mandel† there is a very striking relationship between the quantity of alloxuric bases eliminated in the urine and the temperature of the body in cases of aseptic fevers, indicating that these substances, with possibly other incomplete products of tissue metabolism, are important factors in the production of febrile temperature. We may confidently expect that a thorough study of the physiological action of all the varied katabolic products formed in the body will result in a decided expansion of our knowledge regarding the part these substances may play in normal and abnormal metabolism, and in nutrition in general.

Just here, reference may be made to the many problems in the broad field of nutrition that confront the physiological chemist of the present day. The maintenance of life on a sound physiological basis is one of the practical problems in physiological chemistry, and its solution is not yet attained. We need fuller knowledge regarding the part played by the different nitrogenous food-stuffs, the relative physiological value of animal and vegetable proteid, the relative value of fats and carbohydrates as nutrients aside from their different calorific power, and by no means least a fuller and more accurate knowledge of the true physiological needs of the body for proteid foods. Our present dietetic standards are absolutely false and valueless. Our present conception of the physiological needs of the body is altogether faulty and distorted. Our ideas of the rate and extent of proteid metabolism

* See Burian and Schur, *Archiv für die gesammte Physiologie*, Band 87, p. 239.

† 'The Alloxuric bases in aseptic fevers,' *Am. Journal of Physiology*, Vol. 10, p. 452.

necessary for the maintenance of health and strength are crude and inexact. We place the nitrogen requirement of the healthy man at an absurdly high level, apparently because observation has shown that man is disposed to consume an equivalent in proteid food per day. We need to ascertain by scientific experiment how far such standards are justified; to determine by definite analysis the amounts of nitrogen actually required to maintain nitrogen equilibrium and keep up bodily and mental vigor. Upon the physiological chemist of the present day rests the responsibility for the establishment of nutritive standards that will endure the test of scientific criticism, that will harmonize with daily experience, and that will prove to be physiologically correct.

Further, we need to know more concerning the relative decomposition within the body of the truly organized proteid matter of the tissues, and of the albuminous food-stuffs which, having been digested and absorbed, are in a sense a part of the tissues, but not thoroughly or completely incorporated as an integral part of the living cells. Does the urea of the daily excretion come primarily from the breaking down of the organized proteid, or does it come preferably from the disintegration of the circulating proteid? We recall the famous experiments of Schöndorff, in which blood was made to circulate through the muscles and liver of well-nourished and fasting dogs, with the result that the urea of the blood was increased only when the blood circulated through the tissues of a well-nourished animal. It made no difference with the result whether the blood employed was from a well-fed or a fasting animal; the essential factor was the condition of the muscle tissue through which the blood was made to flow. Schöndorff drew the natural conclusion that the extent of proteid metabolism was dependent upon the nutritive condition of the cells of the tissue, upon the mass of the living cell material, *i. e.,* upon the amount of morphotic proteid present, and that the proteid content of the intermediary fluids, as blood or lymph, was of no moment in determining the rate of urea formation.

We may well doubt, however, if all the urea formed daily under ordinary conditions of life comes solely from the breaking down of the truly organized or morphotic proteid. It is more than probable that the urea has at least a two-fold origin, and, if so, it is an important matter to be able to discriminate between that which comes from the breaking down of the unorganized albumin, and that which is derived from the organized tissues. Unquestionably, the decomposition of organized proteid, the morphotic part of the living protoplasm, is quite different from that of the unorganized pabulum of the cell and surrounding media. Quite possibly, the influences controlling the two lines of metabolism are different; perhaps, there are even different kinds of nerve control.

Equally important is it for the physiologist to know more fully regarding the sources of the carbonic acid resulting from oxidation in the body. What proportion of the ever varying output of this gaseous product of metabolism comes from the oxidation of organized tissue material, and what from the oxidation of circulating carbohydrate and fat and unorganized material in general? We have learned, for example, that the excretion of carbonic acid runs more or less closely parallel with the degree of muscular activity, and we should possess the means of discriminating between the output from true tissue oxidation and that which is derived from extra-cellular sources. A study of the excretion of carbonic acid by fasting individuals, under different conditions of life and activity, would be helpful in throwing light upon this question, and also in giving us a clearer idea of the minimal requirements of the body for non-nitrogenous foods to make good the loss of energy in heat liberation, muscular work, etc. By such a study we might hope for added light upon that much discussed problem, the source of the energy of muscular contraction. While most physiologists are certainly agreed that this energy comes preferably from the oxidation of non-nitrogenous matter, there remain many obscure points upon which we need enlightenment.

We likewise need fuller and more exact knowledge of the ways in which uric acid originates in the body, especially regarding its relationship to intracellular decomposition. Our present understanding of the two-fold origin of this substance—endogenous and exogenous—is most helpful in making clear many formerly obscure points connected with the formation of this substance from the different classes of foodstuffs. To-day, however, we understand quite clearly the genetic relationship between the free and combined purin bases and uric acid, but we are still uncertain whether this substance is formed to some extent synthetically and whether when once formed it is all eliminated unchanged or undergoes oxidation, in part, into less harmful substances. In other words, we do not yet know how far the uric acid which is contained in the daily urine is a measure of the *production* of uric acid for the twenty-four hours. Uric acid and the alloxuric bases are such important substances, in their influence upon health and the general nutritive condition of the body, that it is extremely important for us to know more concerning their origin and their ultimate fate in the body. We may likewise inquire where uric acid is formed. Does it originate entirely in the liver, or are there other depots where it is produced and collected?

Turning our attention now in another direction, we may revert to the relationship between stereochemical configuration and physiological action as a fruitful subject for investigation. Many interesting facts have already been gleaned, and certain general rules or laws have been

formulated, connecting given lines of physiological action with a definite chemical structure. Thus, it is well understood to-day, for example, that all substances which contain a nitro or nitroso group united with, or bound to, oxygen have the effect of dilating blood vessels, while, on the other hand, substances which contain the same nitro or nitroso group joined to carbon have a quite different physiological action, being mostly blood poisons. Further, nitrils, R. CN, tend to produce coma, while isonitrils, R. N = C, are much more toxic and tend to produce paralysis of the respiratory center.* In other words, it is clearly manifest that certain definite groupings within the molecule are the cause of the physiological action of the molecule. At the same time, it is also known that in order to have the physiological action of a substance manifest not only must it contain the necessary group or groupings, but there must likewise be present a second group which has the power of combining with and holding fast to the tissue upon which the physiological action manifests itself. Slight chemical alteration of a substance may, therefore, interfere with or nullify its ordinary physiological action without necessarily altering the physiologically active groups; but by simply changing these other groups through which the molecule ordinarily attaches itself, so that the latter can no longer adhere to the cell substance or tissue protoplasm, there occurs a consequent loss of physiological action.

Another fact clearly understood is that two substances having the same nucleus and like side chains, with an entirely similar grouping, may still be physiologically unlike, owing to a different arrangement in space. This is well illustrated by the dextro- and lævo-rotary tartaric acids, one of which is readily utilized by *Penicillium glaucum* as nutriment, while the other can not be so consumed. Many other illustrations might be cited, especially with various types of organic poisons, all tending to show that physiological action is dependent upon the *arrangement* of the atoms or radicles in space, as well as upon the *nature* of the atoms or radicles. With these facts before us, we see many lines of inquiry presenting themselves, many problems demanding solution, with reference both to pharmacology and physiology.

Confining our attention more especially to physiological matters, we are certainly justified in considering the application of these principles to many of the substances conspicuous in the processes of the body. The work and suggestions of Pasteur and Emil Fischer have indicated certain possibilities regarding the nature and action of enzymes, not to be overlooked. Stereochemical configuration may be just as much responsible for enzyme action, for proteolysis, amylolysis, etc., as any other feature of the active molecule, and how far other lines of physio-

* See Fränkel, 'Ergebnisse der Physiologie,' *Dritter Jahrgang. Biochemie*, p. 291.

logical action may be due to chemical structure and the configuration of the molecule, who can say? One's thoughts naturally turn to the living muscle plasma and the chemical changes that follow or accompany the advent of rigor mortis; to the circulating blood and lymph, and the transformations that occur when these fluids are withdrawn from the protecting influence of the endothelial lining of the living vessels; to the axis cylinder of the nerve fibers and the changes that occur when the fibers are severed from their connection with the ganglionic cells. These, and many other suggestions arise, all calling for a further study of the chemical constitution and stereochemical configuration of the molecules involved, since in the knowledge thus gained may be found the solution of many physiological processes now shrouded in mystery.

The reference just made to nerve fibers and ganglionic cells suggests another problem in physiological chemistry, solution of which has been long deferred, viz., the exact chemical nature of nerve tissue, and the character of the changes involved in the passage of a stimulus or nervous impulse through a nerve to its ending in the muscle or secreting cell. Further, what is the real purpose of the complex myelin surrounding the axis cylinder of medullated nerves, and the corresponding substance imbedded in the gray matter of the brain and cord? These are problems that have long waited solution, and yet they are vital to any clear understanding of the nutritive or other changes that take place in nerve tissue, either in rest or in activity. Nerve tissue is strikingly peculiar in its large content of phosphorized bodies of the lecithin type, cerebrosides and cholesterins. These substances, complex in nature and of large molecular structure, are all alike in having the physical properties of fats. Further, lecithin and the cerebrosides all contain fatty acid radicles in large amount, and in addition lecithin contains the radicle of glycero-phosphoric acid. Moreover, the cerebrosides contain a carbohydrate group yielding galactose on decomposition, so it is plain to see that the bodies which give character to the myelin material are highly nutritive substances with high calorific power. These facts might readily be taken as indicating that the function of the myelin is to nourish the more important axis cylinder, to furnish the necessary pabulum for growth and repair, as well as to meet the daily demand for energy-yielding material.

While we may speculate, however, as to the part these peculiar substances play in the life of nerve tissue, we really possess very little positive knowledge of their true purpose. Indeed, we do not know how these bodies actually exist in the living tissue, as is well evidenced by the utter lack of agreement among physiological chemists as to the entity of the so-called protagon. Whether this phosphorized substance, studied by so many investigators, exists as such in the living tissue, or

whether it is simply an intimate mixture of lecithin, cerebrin and one or more other substances, is not yet settled to the satisfaction of all concerned. Further, it is not at all impossible that the cerebrosides, as well as lecithin and possibly cholesterin, may exist in the living tissue combined with some one or more of the proteids present there. Our lack of knowledge is deplorable, and yet, in the words of Sir Michael Foster, this is one of the 'master tissues' of the body. Surely, considering the preeminent position and controlling influence of this tissue, we may look for a speedy clearing away of the darkness that enshrouds our understanding of the exact chemical composition of nerve tissue, and especially of the way these peculiar substances of the myelin material exist in the living tissue.

Again, we may ask ourselves what is the nature of the chemical changes that take place in nerve tissue; in the ganglionic cells of the gray matter and in the axis cylinder of the nerve fibers? When a muscle contracts there is a measurable chemical decomposition. The energy of muscular contraction comes from the breaking down of non-nitrogenous components of the muscle, and perhaps in some measure from the decomposition of nitrogenous constituents. Further, there is a liberation of heat, a development of lactic acid, etc. When a stimulus is applied to a nerve, on the other hand, no such manifestations of chemical action are apparent. The muscle to which the nerve is attached contracts, the secreting cell pours forth the product of its activity, etc., but there is no noticeable change in the nerve itself, no recognizable liberation of heat, no change of reaction, no output of carbonic acid, that can be detected. Are we to conclude then that the axis cylinder of the nerve fiber acts simply as a conducting agent without itself undergoing any change? Is it to be compared to an electric wire, with the surrounding myelin material, the substance of Schwan, serving as a convenient insulating or protective medium? If we are to accept this view, what are we to say regarding the non-medullated fibers? Do not they need an insulating material likewise? We can argue that the myelin substance is especially adapted for the nourishment of the nerve, that its high potential value renders it peculiarly suitable as a concentrated nutriment, and that its intimate contact with the neuraxis and with the ganglionic cells of the gray matter proclaims its probable use in this direction. Moreover, if we follow this line of argument still further, we may be led to believe that the stimulation of a nerve, its power of conductivity, etc., are associated with chemical decompositions along its axis as marked in their way as those that occur in a contracting muscle fiber. Truly, we have here a multitude of questions, for which at present no satisfactory answers are to be found. The problems are on the surface awaiting solution.

Finally, emphasis must be laid upon a series of problems in physio-

logical chemistry, true solution of which will do much to explain natural and artificial immunity, the action of toxins and antitoxins, the bactericidal action of blood sera, the effect of oxidizing enzymes of animal and vegetable origin upon toxins of various kinds, etc. Ehrlich's theories regarding the protection furnished by antitoxic and bactericidal serums, so elaborately devised, constitute a working hypothesis of great value, but we need much additional knowledge concerning the nature and action of the so-called complements and anticomplements, of amboceptors, of haptophor groups, of agglutinins, of precipitins and of hemolysis. The physiological chemist studies with care the important and suggestive work being carried forward by the many brilliant investigators in pathology and bacteriology, with the feeling, however, that the true explanations for most of the phenomena in question are chemical, and that the actions and interactions involved are chemical ones, to be eventually made clear by a fuller chemical knowledge of the toxic and antitoxic substances themselves, and of their alteration and combination under different physiological conditions.

The well-known natural immunity possessed by some animals toward certain diseases, together with the difficulty experienced by most micro-organisms in developing in the healthy body; a difficulty which at once disappears when from any cause the tissues of the body lose their original vitality and vigor, all point to the presence in the healthy body of certain general or specific substances which are directly deleterious to the micro-organisms. Such substances are obviously bactericidal, and it is equally plain that in the bodies of many species of animals there are specific antisubstances present which are lacking in other species, thereby explaining the natural immunity of the former towards certain diseases. As is well known, blood serum possesses, as a rule, a bactericidal power upon most micro-organisms, and we have every reason to believe in the existence of specific substances in the serum which exert some influence upon the growth and development of micro-organisms, and also upon the toxic products they tend to elaborate. These protective substances—the alexins of Buchner—appear to be proteid in nature, resembling globulins, since they are precipitated from serum by the action of certain strong solutions of alkali salts, as sodium sulphate. We know, however, very little regarding their chemical nature aside from the fact that they are obviously very complex, although perhaps even this point is not quite certain. These protective substances are presumably elaborated by the leucocytes of the blood and lymph, cells rich in nuclein and nucleoproteid material. Doubtless, also, some of the gland cells in the body have a corresponding action; statements which, if true, tend to emphasize the possible proteid nature of the protective substances.

While in a general way we may say that the natural immunity to

certain bacteria possessed by some animals is due in large measure to an inhibition of the growth of the micro-organism, it must also be remembered that there is in many species a distinct immunity to the action of the poison which the specific micro-organism produces. This immunity depends either upon a destruction of the poison as by oxidation, upon a combination between the poison and some constituents of the active protoplasmic cells of the body, thereby rendering the poison inactive, or, lastly, to some action of the specific protoplasmic cells of the body usually affected by the poison, by which the latter is unable to combine with the cells upon which it ordinarily acts. All these suggestions, however, imply chemical reactions of some kind, and obviously should be understood for a betterment of our knowledge upon this important matter.

Again, the specific immunity which shows itself after exposure to a given disease, so that a second infection becomes practically impossible, can be explained satisfactorily only on chemical grounds, viz., by the presence in the blood and lymph of certain protective or immunizing substances which presumably originate through chemical changes in the blood-serum, under the influence of the bacteria causing the disease. These are chemical substances, formed through chemical decompositions or alterations of normal constituents of the blood, and obviously we need to know more of their exact nature.

Following Ehrlich's views, specific antitoxins, bactericidal sera, etc., result from the overproduction of molecules in cells which are sensitive to the action of toxins and other bacterial products. Antitoxins so formed unite with toxins, and the so-called complementary bodies and the bactericidal antibodies combine with the bacterial cells, thus affording protection. These processes of alteration and combination, however, are presumably all chemical, involving either alteration of chemical structure, or direct combination of bodies chemically the opposite of each other. Further, the so-called haptophor groups of the toxin molecule are probably represented in fact by chemical groups or radicles, which owe their power of combination with corresponding groups of other cells to chemical affinity. Again, the complementary body, normally present in all healthy blood sera and which is needed along with the specific antibody for the destruction of bacterial cells, must owe its activity to the power of chemical combination. Hence, we have presented to us at every turn the question of the chemical nature of these various substances, toxin and antitoxin, complement, receptor, haptophor, etc., which are of such vital importance in the production and maintenance of immunity and protection. Surely this is one of the most important problems of the present day in the domain of physiological chemistry, and calls for both patience and skill of the highest order in its solution.

THE AGRICULTURAL DISTRIBUTION OF IMMIGRANTS.

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MANY of the evils resulting from the enormous immigration of aliens into this country during recent years have been much aggravated by the congestion of these aliens in the slums of our large northern cities. For this reason, most of those who have studied the immigration problem seriously have come to the conclusion that if these immigrants could be removed from the slums, and distributed over the agricultural districts of the west and south, all the difficulties which are now met with in educating and Americanizing these foreigners could easily be disposed of. The vastness of the problem of the city slum, and the impossibility, even with unlimited resources of men and money, of permanently raising the standards of living of many of our immigrants as long as they are crowded together, and as long as the stream of newer immigrants pours into these same slums, has naturally forced itself upon the minds of thinking persons. This note was struck in the last Annual Report of the Boston Associated Charities in the following words: "With an immigration as unrestrained as at present, we can have little hope of permanent gain in the struggle for uplifting the poor of our cities, since newcomers are always at hand, ignorant of American standards." And in a recent study of the Chicago Stock Yards strike, in which the miserable conditions are described under which the newer immigrants employed in the yards live, we learn that "from the poorest parts of Bohemia, Poland, Lithuania, and Slavonia, these immigrants have poured in great overlapping waves into the stock yards. The standard of living of each wave rises slowly, *constantly sucked down by the lower standards of the waves behind.*"*

The fact has become increasingly obvious during the past few years that in the 'Little Italys,' the 'Little Russias,' the 'Little Syrias,' in our city slums, we are finding more and more difficult and burdensome problems of public and private charity; of police; of education; of religious training; of public health.

> Go down to Little Italy, says a writer of New York, and it is Italy. It has not only its market of Italian foods and other stuffs. It has its Italian feast days and processions and celebrations; and there are thousands of persons there who can hardly know that they have come from Italy. . . . It is a similar story, of course, that has many a time been told about the Ghetto. It differs

* The italics are the present writer's.

little from the Ghettoes of Europe, except for the touch of kindlier fortune. . . . A Syrian might go to sleep at home, and if he could sleep eight or nine days he might wake up in New York, and be perfectly at home in the Syrian quarter. . . . These quarters have long been here, and they are in all our cities. But the new thought is of their apparently indefinite extension.

The only remedies for such conditions are: a considerable restriction of immigration, *and* (not *or*) the distribution of the slum populations through the agricultural districts of the country. Although congress has repeatedly been asked, in the strongest terms, by very influential bodies of citizens all over the country, to enact further restrictive legislation, no laws at all adequate to meet the situation have been put upon the statute books. The powerful influences of railroad and steamship companies, and of large employers who want 'cheap' labor, have been able to turn the scale against what the majority of Americans without question believe to be the best for the country. The first of the two remedies above referred to not having been secured, there has been a decided swing of opinion in favor of the second. Any one who reads over recent literature on immigration will find constant reference to the 'solution of the immigration problem by the agricultural distribution of our immigrants.' That charity workers should have been so long finding out this (supposedly) excellent and effective remedy, which is lauded as if it alone were to be the panacea for all the ills resulting from immigration, is much more surprising than that the steamship and railroad interests of this country should be doing their utmost to 'boom' it as *the one* solution of the immigration problem, always carefully concealing their own interest in the matter, which is to increase their receipts through the transportation of all these thousands of immigrants, to secure cheaper labor, *and to turn public attention away from the need of further restrictive legislation.* The advocacy of the distribution plan by those having affiliations with transportation interests, or with enterprises which desire 'cheap' labor, especially in the less thickly settled parts of our country, will bear careful watching.

The relief which a distribution of the inhabitants of our city slums seems sure to bring to the charity workers and the philanthropists of our large northern cities, and the fact that such distribution is also being systematically, though not openly, advocated by powerful transportation and capitalistic interests, have caused this new idea to be welcomed with great enthusiasm, the selfish and unselfish interests working along the same lines, as is seldom the case in immigration matters. In all this enthusiasm for the new remedy it is natural that there is danger of going too fast and too far; there is a likelihood that we are urging distribution from our congested districts without caring sufficiently where the people whom we are anxious to get off our hands

go to; whether the removal will accomplish as much as is expected of it; whether the people among whom these foreigners are scattered really want them; whether removal on a wholesale scale will not develop new agricultural colonies of aliens in which some of the evils of the slums will be reproduced anew; whether the effects of such dispersion on the communities among which the new settlers are located will be for the best of those communities in the long run; whether—and this is perhaps the most important point of all—wholesale distribution will really relieve the city's burden. It is because the writer realizes that distribution is a remedy for existing evils which may well be added to the more fundamental one of a further restriction of immigration, and because he realizes that many persons have advocated the distribution idea without giving it careful thought, that the writer desires to call attention to a few points which need discussion before we go any farther in the matter.

1. *Expense.*—To scatter the city slum populations on any scale large enough to be at all effective would require vast sums of money, if the thing is done intelligently. It is not enough simply to pay the fares of hundreds of thousands of persons from the cities to distant points in the west or south, but provision should be made for the new arrivals when they reach their destination, and they usually need care and oversight for a good many years. It is obvious that if immigrants who have just landed can be persuaded, or forced, to go at once into the country districts at their own expense, or at the expense of some railroad or capitalist desiring 'cheap' labor, philanthropic persons would be saved the immediate cost of the transportation. It must be remembered, however, that wholesale distribution by railroads or capitalists is not likely to be controlled by a desire to do what is best for the immigrants, nor for the people among whom they are scattered, but rather by purely selfish interests. Furthermore, the natural tendency of most of our immigrants is to remain in the larger cities, because of their desire to be with large numbers of their fellow-countrymen, because the majority of the newcomers have very little money and because the cities are the centers for manufacturing and mechanical industries, which are on the whole more remunerative than agriculture. The average amount of money brought by each immigrant during the last five years was sixteen dollars. In the Report of the Industrial Commission it is shown that the amount of money brought by immigrants from northern and western Europe averages considerably greater than that brought by those from southern and eastern Europe, but it is the latter class which it is chiefly desired to distribute. To be really effective, thousands of families should be removed from the slums of New York, and Chicago, and Boston, and other cities, every year, and the incoming of two or three times as many

families of newer immigrants of the same standards of living should be checked.

2. *Success thus far attained not altogether Encouraging.*—The attempts which have already been made along the line of the distribution of recent immigrants from our city slums, admirable as they are, and much as they deserve support, have on the whole been sadly ineffective. The Jewish Industrial Removal Society of New York, with the aid of the Hirsch fund, has distributed many Jewish families in the country, partly in agriculture, but usually in trade. Last year this society sent more than 3,000 persons to 45 states, three per cent. being on record as having already drifted back into cities. Similar societies are at work in Chicago, Philadelphia and Boston, and the Italian societies are doing the same sort of work. Although in most cases the individuals thus removed have fared better in their new homes than in the slums, yet taken as a whole, the success thus far attained is not so encouraging as to lead thoughtful persons to be sanguine about the entire practicability of carrying out a successful scheme of wholesale distribution along similar lines. And while there have been successes in the past, there have also been many dismal failures, and in almost all such attempts very great difficulties have been met.

3. *Most of our Newer Immigrants not adapted to an Agricultural Life.*—It is a mistake to suppose that all immigrants can be turned into successful farmers simply by sending them into the country. The commissioner of immigration at the Port of New York says in his last annual report (1903): 'Thousands of foreigners keep pouring into our cities, declining to go where they might be wanted because they are neither physically nor mentally fitted to go to these undeveloped parts of our country, and do as did the early settlers from northern Europe,' and this is especially true of most of the immigrants who, because of the steamship rate war, have been coming over to this country during the summer of 1904 for less than $10 a head. Such a rate makes it possible for the most ignorant and the most depraved inhabitants of Europe's slums to come here. Would a railroad fare of say $5 from Chicago to southern California induce the best or the least desirable of Chicago's residents to take advantage of the opportunity to go west? Long residence of successive generations in the Ghettoes of Europe has unfitted most of the Jews to be independent farmers; the Syrians and Armenians take naturally to non-agricultural occupations, and so it is with others. The majority of our recent immigrants from southern and eastern Europe are too poor and too ignorant to be fitted for a successful farming life. In this connection Mr. Gustavo Tosti, Acting Consul-General of Italy in New York, who has given much time to the study of the conditions of Italians in this country, says:

> There is a misleading idea in certain quarters that 'the agricultural distribution of Italian immigrants' should be obtained simply through the employment of a large number of Italians as farm workers and farm hands. This would be only a palliative measure. The character of agricultural work is, by its very nature, precarious. The Italian immigrants would thus find employment during a few months of the year, when, for instance, at harvest time, there is an enormous demand for labor. . . . But after a comparatively short period of occupation they would lapse into enforced idleness, which would undoubtedly drive them back to the industrial centers. The only way to get at the root of the question is to transform a large portion of our immigrants into landowners or farmers.

To transform ignorant laborers, with but a few dollars in their possession, into landowners, is not a matter of a day or a year. It involves an expenditure of time and money. It is a matter of the assimilation of the immigrant and of the elevation of his standards of living. Thus, neither the interests of those states which desire immigrants who shall at once buy their land, nor the best interests of the Italian immigrants themselves, as set forth by Mr. Tosti, are met in a wholesale distribution of ignorant farm laborers. The difficulty of having large numbers of farm laborers in idleness for much of the time, to which Mr. Tosti also refers, is already present, as may be seen in the following statement, clipped from a newspaper of last summer:

> Several of the largest planters in the delta have made contracts with the labor agencies in New York to secure for them gangs of Italian immigrants, who are now being brought south by the coach load. . . . The Italian laborers who are now being imported will not have very much to do until the cotton-picking season opens, and the immigrants will be maintained by the planters in comparative idleness until picking begins.

4. *Do the Country Districts want the Kind of Immigrants whom it is proposed to send to them?*—No distribution of our immigrants should be thought of if the states to which they are to be sent do not welcome them. A few years ago, the U. S. Immigration Investigating Commission asked the governors of the different states what nationalities of immigrants they desired, and in only two cases was any desire expressed for Slavs, Latins, Jews or Asiatics, and both of these two cases related to Italian farmers, with money, intending to become permanent settlers. A canvass of the same kind, made within six months by some gentlemen who are interested in the distribution scheme, showed that these preferences have undergone no appreciable change. In every case, in this recent canvass, the officials protested against the shipment of southern and eastern Europeans from the city slums into their states. In the south to-day, owing to the lessened efficiency of the negro, the greater demand for field laborers, and the movement from the country into the towns, the need of pickers in the cotton fields is very great in some sections, and the demand for vast hordes

of any kind of laborers—even the most ignorant of newly-arrived aliens—is referred to in the newspapers. But this demand for the cheapest labor without regard to the effects which the importation of such laborers will have upon the community, apparently comes from a comparatively limited number of capitalists, and from the southern railroads. The majority of the thinking people of the south, if they know something about the evils which have come in the train of the newer alien immigration in the north, will not look with favor upon the wholesale importation of cheap and ignorant alien labor. Several of the southern states have emphatically stated what nationalities of immigrants they want, and their preferences are for people from the northern United States and for northern Europeans. Thus, South Carolina, concerning which a leading authority on the south has said that there is no state in the Union in which 'there is a more general desire for more white men who are willing to work with their hands,' has, through its legislature, recently voted that its new commissioner of agriculture, commerce and immigration must confine his activities in securing new immigrants to 'white citizens of the United States, citizens of Ireland, Scotland, Switzerland, France and all other foreigners of Saxon origin.' The general demand in the south and west is for the intelligent 'settler who has means of purchase,' not for the newly-arrived, ignorant and penniless immigrant, who 'would require the fostering care of government or of wealthy private societies.' The land companies and large private owners of land are in search of purchasers who have resided in the United States for some years and are familiar with American customs, or else of immigrants with some money, coming from northern Europe. To send out to other states thousands of aliens who are not really desired there, simply because we think we can thus relieve ourselves of an unpleasant burden, is much like throwing our weeds over our neighbor's fence, into our neighbor's garden.

There doubtless is need of labor in the south to-day; the Italian is unquestionably well fitted to do much of the work which needs doing; and in those parts of the southern country where Italians have settled, they have proved their ability and willingness to do work at least equal to that of the negro in the cotton-fields; they are praised as industrious, thrifty, good citizens, frugal, and as having increased land values. On some railroads, also, they are reported as being satisfactory laborers. On the other hand, it must be noted that the most successful settlements have been those of *northern* Italians; that the greater desirability of the northern Italian is generally recognized wherever experience has been had with both northern and southern Italians, and that thus far the number of Italians in the south has been small and practically none of the less happy consequences of the congestion of separate nationalities have been noted. The favorable reports which have

recently been made by Chevaliers Rossi and Rossati as to the conditions and prospects of Italian immigrants in the Mississippi delta; the plans which are being formed for the transportation of tens of thousands of Italians to the southern states, either by the new direct steamship line from Italy to New Orleans or by the train-load from the slums of New York and of other northern cities or direct from Ellis Island—it all sounds like an attractive program for the Italians. But does the scheme sound altogether as attractive to those southerners who have the best interests of their own country at heart, and who fully appreciate how grave are the social and political responsibilities which already weigh upon their fair land? The south should think twice before it allows its capitalists and its railroads to flood the country with 'cheap' and ignorant alien laborers. A leading newspaper of the south has recently said that the southern states want no such immigrants as have crowded the east side of New York and the factories of New England. Unless steps are taken by the south to prevent it, much the same conditions may be developed there within a few years.

5. *Wholesale Distribution soon involves Foreign 'Colonies.'*—One of the objects of the agricultural distribution of our recent immigrants is to prevent the congestion of the different nationalities in colonies, by scattering these people, as it is said, 'among the native population.' Now while distribution in country districts does, of course, in all cases, prevent such congestion as is characteristic of city slums, the tendency for recent immigrants from southern and eastern Europe to herd together in settlements of their own is almost as marked in the country as in the cities. Moreover, this unfortunate tendency—unfortunate because it retards assimilation—is in many cases fostered by philanthropic societies and by railroad and land companies. The following headings, clipped at random from newspapers of recent dates, show how distinctly the much-talked-of 'agricultural distribution' of our newer immigration tends towards the formation of alien colonies. "Poles going to Michigan. The Milwaukee branch of the Polish National Alliance of America has purchased 50,000 acres. It is planned to establish other large colonies." "The latest phase of the New Zion problem is to purchase a large tract of land in Wisconsin for the immigrant Jews from Roumania and from Russia." "Jewish colony for Michigan. Russian and Polish refugees to settle on the line of the Escanaba and Lake Superior R. R. They are brought by a committee in New York." "Hungarians coming to Texas. About 500 families from southern Austria to settle on line of Southern Pacific." "Hungarian colony planned. A $200,000 company to establish town sites in Jackson Co., Arkansas. E. E. Barclay, Immigration Agent of the St. Louis, Iron Mountain and Southern R. R., is the chief stockholder." (The last sentence is significant of the moving

spirit behind many of these new colonies.) "Russian Jew colony in Alabama. The colony will consist of 40 Russian Jew families, and they propose to establish a manufacturing settlement, principally for the making of *clothes.*" And so on, *ad libitum.* It is obvious that the establishment of such alien colonies is not conducive to thorough and rapid assimilation, and that, if this is the tendency of 'agricultural distribution,' the benefits to be derived from such distribution are certain to be much lessened.

The present view regarding our alien immigration is not that of criticism of, nor of prejudice against, any one nationality or group of foreigners. Hence the frequent outbreaks of impassioned defense of this or that nationality are both unnecessary and misleading. The sober thought regarding the dangers of immigration is that of apprehension that an ever-increasing mass of our alien population which keeps its identity is a great evil in our democracy. These alien colonies have for years been found in our city slums; the present movement is evidently going to plant them all over the country, in the farming districts. The thought of danger in alien colonies is, after all, not as new as many writers would have us believe. Washington, in a letter to John Adams, dated November 27, 1794, wrote as follows: "My opinion with respect to emigration [immigration] is that except of useful mechanics and some particular descriptions of men and professions, there is no need of encouragement, while the policy or advantage of its taking place in a body (I mean the settling of them in a body) may be much questioned; for by so doing they retain their language, habits, and principles, good or bad, which they bring with them." And Franklin expressed it as his belief that a homogeneous population is necessary to a successful democracy.

6. *Effects upon the Sections in which the Distribution takes Place not always good.*—To scatter among our rural communities large numbers of aliens whose standards of living are such that they are willing to work for the lowest possible wage, is to expose our native farming population to a competition which is distinctly undesirable. In the corn belt of the west, as Professor T. N. Carver has recently shown, the newer immigrants, because of their lower standards of living, have been able to put more money into land, buildings and equipment than the native American farmer; and hence have an advantage in the struggle for existence. Scattering our alien population of the more ignorant races simply spreads more widely the evils which result from exposing our own people to competition with the lower classes of foreigners. Again, in the case of the agricultural distribution of Italian and other alien laborers through the south, while it is perfectly true that these aliens will supplant the negroes in many—probably in most—occupations, the effect will undoubtedly be to cause a

migration of the negroes to the cities—a result which those familiar with the conditions of negroes now congested in cities can not fail to view with the greatest alarm. Lastly, the more widely we scatter the newer immigrants, the more widespread will be the effect of the competition with the lower grades of aliens in causing a decrease in the birth rate among the older portion of our population. American fathers and mothers, as the late Gen. Francis A. Walker first pointed out, and as leading authorities have since reiterated, naturally shrink from exposing their sons and daughters to competition with those who are contented with lower wages and lower standards of living; *and therefore these sons and daughters are never born.* The agricultural distribution of immigrants from southern and eastern Europe, and from Asia, will hasten still more the replacement of the native by foreign stock.

7. *Agricultural Distribution of Immigrants will not solve the Immigration Problem.*—But few of those who are now urging the necessity of relieving the city slum burden by distributing the slum population realize that such distribution will not, and can not, of itself, lead to any relief, as long as the tide of new immigration flows on unchecked. As Professor John R. Commons, one of the leading authorities on immigration in the United States, has recently said:*

> To relieve the pressure in the cities without restricting the number admitted only opens the way for a still larger immigration; for, strangely enough, emigration has not relieved the pressure of population in Europe. In no period of their history, with the exception of Ireland, have the populations of Europe increased at a greater rate than during the last half century of migration to America. As a relief for current immigration, agricultural distribution is not promising.

It needs but little thought to convince any one that were it not for the continued influx of hundreds of thousands of ignorant and poverty-stricken aliens each year, there would, in few years, remain no such serious problem of Jewish charity, or of Italian charity, or of any other charity in our country as at present. It is a fact, so obvious as to need no argument in support of it, that the more we try to reduce the pressure of competition among the alien immigrants in our congested city slums, the more we shall encourage other aliens, as ignorant and as poor, to come over and take the places thus vacated. Distribution and a reduction in the numbers of our immigrants: both of these remedies are needed. Private charitable agencies are not likely to have money enough to carry out any scheme of distribution on a large scale; that will be attended to by the capitalistic interests which want the cheapest labor obtainable. Charitable societies and individuals should do their best to see that this distri-

* *The Chautauquan*, May, 1904, 224.

bution is intelligently directed, and that the alien colonies which are being formed in our farming districts do not become a menace. As to a reduction in the numbers of our alien arrivals, that is a work in which all who have at heart the best interests of their country, of the immigrants who are now here, and of those who are still to come, should join hands to accomplish. As Mr. Robert Hunter has recently said:* "If we let the steamship companies and the railroads, wanting cheap labor, alone, we shall not decide what immigrants will be better for coming, and what ones the country most needs. They will decide it for us." There are two feasible remedies for reducing immigration now before congress. One, the illiteracy test, which has the support of the great majority of those who have studied the immigration problem carefully, and which has been strongly endorsed by President Roosevelt, the commissioner-general of immigration, and the boards of organized charity throughout the country. The other suggested by Congressman Robert Adams, Jr., of Pennsylvania, which would restrict to 80,000 the number of new immigrants who could come to us from any one foreign country in any one year. In his last Annual Report the Commissioner of Immigration at New York said:

> I believe that at least 200,000 (and probably more) aliens came here (last year), who, although they may be able to earn a living, yet are not wanted, will be of no benefit to the country, and will, on the contrary, be a detriment, because their presence will tend to lower our standards; and if these 200,000 persons could have been induced to stay at home, nobody, not even those clamoring for more labor, would have missed them. Their coming has been of benefit chiefly, if not only, to the transportation companies which brought them here.

To exclude this surplus of undesirable aliens, and to distribute the others over our farming districts where they can find suitable work and where they are wanted, is one of the most important problems before the people of this country.

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* *The Commons*, April, 1904, 117.

THE CONCEPTIONS AND METHODS OF PSYCHOLOGY.

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ONE of the verses in the treasure-house of Greek letters warns us against calling any man happy before he is dead. The greatest living English author lets one of his favorite characters say: 'But does incessant battling keep the intellect clear?' Such reflections may well lead us to distrust any attempt, by one in the ranks, to sum up the fundamental conceptions and methods of a science, especially of a young and growing science. It may be the prerogative of the student of psychology to write the biography of an infant, but he has not hitherto penetrated very far into its real life. I disagree completely with the eminent psychologist to whom the plan of this great congress is chiefly due when he claims that 'the presuppositions with which a science starts decide for all time the possibilities of its outer extension.' Sciences are not immutable species, but developing organisms. Their fundamental conceptions and methods at any period can only be approached by a research into work actually accomplished. Had time and circumstance permitted, I should have attempted to make an inductive study of the contents and methods of psychology rather than to prepare three quarters of an hour of generalities and platitudes. But as even the pedant knows, 'die Kunst ist lang, und kurz ist unser Leben.' The court poet must console himself for the deficiencies of his ceremonial verses by reflecting on the honor of being permitted to write them.

The concept of a science is an abstraction from an abstraction. The concrete fact is the individual experience of each of us. Certain parts of this experience are forcibly and artificially separated from the rest and become my science of psychology, your science of psychology, his science of psychology. From all these individual sciences, shifting not only from person to person but also from day to day, there arises by a kind of natural selection a *quasi* objective science of psychology. In a well-bred science, such as chemistry, the conventions have become standardized; the dogmas impose themselves on the neophyte. But projectiles as small as ions or electrons break up the idols, and the map

* An address at the International Congress of Arts and Science, St. Louis, September, 1904.

of science is remodeled more quickly and completely than the map of Asia.

Psychology has never had a well-defined territory. As states of consciousness appear to be less stable and definite than the objects of the material world, so the science of psychology is more shifting in its contents and more uncertain in its methods than any physical science. We are told indeed in our introductory text-books that psychology is the science of mind and that mind and matter are the most diverse things in the world. It is said further that psychology is a positive science and is thus clearly distinguished from the normative disciplines, such as logic and ethics. Words are also used to set psychology off from sociology, history, philology and the rest. But while all these verbal definitions may satisfy the college sophomore, they must be perplexing to the candidate for the doctor's degree.

The distinction between mind and matter is one of the last words of a philosophy which does not yet exist, rather than an axiom of every-day experience on which preliminary definitions may be based. We can not rest satisfied with an empirical psychology in which the distinction is self-evident, an epistemology in which it is explained and a metaphysics in which it disappears. It may be that we follow Descartes rather than Aristotle in our psychology, not so much from the needs of the science itself as from the demands of the church, on the one hand, and of physical science, on the other. The church required souls that might be saved or damned; physics wanted a world independent of individual perception, and as the methods of exact science were extended to the human body it became a part of the physical system.

To us who have been brought up in the orthodox tradition, the views of some of those who have passed from natural science to metaphysics seem decidedly naive. Thus Mach entitles the concluding section of his *Science of Mechanics* 'The Relations of Mechanics to Physiology,' when he is discussing not the question as to whether vital phenomena may be reduced to the laws of matter in motion, but the relations between sensations and the physical stimulus. Pearson tells us in his *Grammar of Science* that if the cortex of one brain were connected with another by a commissure of nerve substance, there would be 'physical verification of other consciousness.' Ostwald lets energy do hermaphroditic service in the physical and the extra-physical households.

But it is not certain that such ingenuous commingling of the mental and the physical worlds is more repugnant to common sense or natural science than the logical subtleties of the schools, which undertake to define, relate or obliterate them. It is generally assumed that a psychologist must be either an interactionist or a parallelist. Ac-

cording to the definitions with which our psychologies start, it is indeed true that mind and matter must either interact or in some way correspond without interaction. If the psychologist asserts that each brain is a center for the creation of new energy or for interference with the configuration of a material system, he obviously subverts the principal generalizations of physical science. He doubtless has a right to do so, but in the same sense as the cow has a right to stop the locomotive engine. If, on the other hand, the psychologist modestly admits that mind does not affect the physical order, he runs counter to the principal generalization of biological science. If pleasure and pain, memory and forethought, are of no use in the struggle for organic survival, why should they ever have evolved?

It requires less temerity to question the theories of biology than to deny the laws of physics. The survival of the fit may be regarded as a truism rather than as a discovery, if we call that fit which does survive. But fitness of this kind is so protean in its manifestations in organic nature that the formula becomes somewhat vague. If an animal is inconspicuously colored, it is protective coloration and so useful; if conspicuously colored, it is directive coloration and so useful. It is somewhat difficult to guess the utility of the fantastic shape and color of each deep-sea fish that lives in perpetual darkness. Then there are admittedly correlated variations, by-products of evolution, diseases and the like; it may be that consciousness is that sort of thing. If some kinds of consciousness, as the sense of beauty, are of no use in the struggle for existence, all the rest may be equally useless—an efflorescence exhibited when there is friction due to lack of adjustment between the organism and its environment. Finally, and most plausibly, it may be argued that minds have evolved in answer to final causes, and that organic evolution must adopt the principles of psychology rather than prescribe to it.

The interactionist seems to be in a worse plight than the parallelist in the conflicts with our sister sciences, but the case is different before the court of common sense. The present writer can not conceive how the parallelist gets outside the limits of consciousness. Why does he want any thing to run parallel with the only thing he knows? He becomes at once a subjective idealist, and there may be no harm in that. But when the subjective idealist wants to live in a world with other men, he reinvents the distinctions that he had verbally obliterated. What he knows about the physical world is what his senses and the physicists tell him; if he likes to call it all consciousness or the unconscious, mind-stuff, will or God's thought, this may be emotionally stimulating, but no fact or law is thereby altered. The world may be God's thought, without in the least preventing the parallelist from thinking illogically.

If clarified experience is subverted by logic, we can of course become sceptics; but it is safer and wiser to wait awhile. Experience may become more clarified, our premises may prove to be at fault, even our syllogisms may be false. When it is said that a psychologist must be either an interactionist or a parallelist, and we find insurmountable difficulties in the way of his being either, the trouble may be with the original assumptions. Matter and consciousness may not be two entities set over against each other. A perception may be both a part of my consciousness and a part of the physical world; an object may be at the same time in a world of matter in motion and in the microcosm of my individual mind. As my colleague, Professor Dewey, starting from an idealistic standpoint, claims, we may simply be giving different names to activity when it is tensional and when it is relatively stable; or as my colleague, Professor Woodbridge, starting from a realistic standpoint, suggests, the relation of consciousness to objects may be analogous to that of space to objects.

As I have said, the relations of mind to body and the distinction between consciousness and matter are the last word of a philosophy that is not yet written, and I have no competence or wish to discuss them here. But the task has been assigned to me of considering the scope, conceptions and methods of psychology, and it is my business to define the field of psychology or to acknowledge my inability to do so. I must choose the latter alternative. I can only say that psychology is what the psychologist is interested in *qua* psychologist. If it is said that this is tautological, it may be replied that tautology is characteristic of definitions. If psychology is defined as the 'science of mind' or, what in my opinion is better, 'the science of minds' the tautology is equal, and it appears to be more possible to determine by an inductive study the professional interests of psychologists than to define the nature of mind or consciousness. Further, I am not convinced that psychology should be limited to the study of consciousness as such, in so far as this can be set off from the physical world. Psychology apart from consciousness is doubtless an absurdity, but so also is mathematics or botany. I admire the products of the Herbartian school and the ever-increasing acuteness of introspective analysis from Locke to Ward. All this forms an important chapter in modern psychology; but the positive scientific results are small in quantity when compared with the objective experimental work accomplished in the past fifty years. There is no conflict between introspective analysis and objective experiment—on the contrary, they should and do continually cooperate. But the rather widespread notion that there is no psychology apart from introspection is refuted by the brute argument of accomplished fact.

It seems to me that most of the research work that has been done by me or in my laboratory is nearly as independent of introspection as work in physics or in zoology. The time of mental processes, the accuracy of perception and movement, the range of consciousness, fatigue and practise, the motor accompaniments of thought, memory, the association of ideas, the perception of space, color-vision, preferences, judgments, individual differences, the behavior of animals and of children, these and other topics I have investigated without requiring the slightest introspection on the part of the subject or undertaking such on my own part during the course of the experiments. It is usually no more necessary for the subject to be a psychologist than it is for the vivisected frog to be a physiologist.

James and Wundt agree in telling us that the experimental method is chiefly of use as a servant of introspection; indeed James says that there is no 'new psychology,' 'nothing but the old psychology which began in Locke's time, plus a little physiology of the brain and senses and theory of evolution, and a few refinements of introspective detail.' But our leaders in psychology have become our leaders by belying such partial statements. Although neither Wundt nor James has attempted any considerable experimental research, yet we look up to them as the founders of modern psychology. Wundt's original and laborious *Physiologische Psychologie,* the Leipzig laboratory and the *Philosophische Studien* have been in large measure the foundation stones of experimental psychology. The broad opportunistic treatment of James, instinct with genius and fearless of logical inconsistency, has been of immense service in freeing psychology from traditional fetters. I see no reason why psychology, at least the psychology of twenty years ago, may not be said to be the subjects treated in James's *Principles of Psychology* and Wundt's *Physiologische Psychologie* with such additional subjects as other psychologists have included or might have included in their treatises.

When the introspective purist says that the treatises of Wundt and James are potpouris of sciences, or that the kind of work that some of us have attempted to do belongs to physiology or to anthropometry or nowhere in particular, there is a natural temptation to reply that much of introspective and analytic psychology belongs to art rather than to science. Such things may be ingenious and interesting, like the personae of Bernard Shaw or the mermaids of Burne Jones, but we don't expect to meet them in the street. An attitude of this kind would, however, be as partial as that which it seeks to controvert. Let us take a broad outlook and be liberal in our appreciation; let us welcome variations and sports; if birth is given to monstrosities on occasion, we may be sure that they will not survive.

Any attempt at *a priori* limitation of the field of a science is futile.

Even if, for example, consciousness and matter in motion were distinct and distinguishable, this would be no argument against a science of physiological psychology. Cerebral and psychical phenomena form one series, and if we have at present no adequate science which concerns itself with this series, it is owing to ignorance of facts, not at all to logical limitations. Matter, time, space and the differential calculus may be as disparate as possible, but are brought together in the science of physics. If the psychologist can not be shut out of the physical world, still less can he be excluded from the sphere of the so-called normative sciences. If any one takes a modern work on ethics or esthetics and tries to separate the treatment of 'what is' from that of 'what ought to be,' he will find himself engaged in an idle task.

It appears that the limits of a science are set largely by a psychological constant. A single science has practically the range that can be covered by a single mind or man. From Aristotle to Hobbes and Descartes there were philosophers who could master nearly the whole range of knowledge and advance it in whatever direction they cared to turn. But even in this period as knowledge accumulated, specialization began, and we find astronomers, anatomists and other students of particular sciences. After Galileo and Newton the physico-mathematical sciences became completely divorced from the descriptive natural sciences, while psychology remained under the shelter of philosophy. It was only in the second half of the nineteenth century that the accumulation of certain facts and theories warranted their becoming the chief interest of a psychologist, and even yet it is more usual for a man to pass through a psychological period than to be a permanent psychologist.

While the first result of increased knowledge has been the establishment of a number of sciences—say a dozen or a score—which have secured proselytes and to a certain extent limited and directed their activities, the further increase of knowledge must break down the artificial limitations. The late emergence of psychology has made easy an elective selection of material. We not only have psychologists who are also philosophers, but psychologists who are also physiologists, anatomists, pathologists, zoologists, anthropologists, philologists, sociologists, physicists or mathematicians. Psychology is and will increasingly become united with professions and arts, with education, medicine, music, painting and the rest. Even sciences remote from psychology, astronomy, for example, may have sufficient points of contact to occupy the entire time of a specialist. We not only have combinations between the orthodox sciences, but cross-sections through them, which may to advantage occupy the student, and which have full rights to be ranked as sciences. The phenomena of vision, for example, are scattered among the sciences of psychology, physics, physiology, anatomy, anthro-

pology, zoology, embryology, pathology, chemistry, mathematics, etc.; they are important factors in certain fine and industrial arts; they are the basis of one of the most important medical disciplines. Why should not a man be a 'visionologist' or 'sightonomer'? When President Hall gives us an original and unique book on adolescence, nothing is gained by attempting to assign it to one of the conventional sciences. The work of Dr. Galton appears to me to be particularly unified, but it does not belong to psychology, nor to any other science. Why not call him an opportunist, or a liberal unionist, or a Galtonist, or better still call him no name at all?

In objecting to an artificial limitation of the field of the psychologist, I by no means want to aggrandize his office or to let psychology eat up the other sciences. The student of psychology is limited by the capacity of the human mind and of his own particular mind; he can, on the average, cover a range about as large as that of the student of any other science. If he would gladly get, he would also gladly give. If he is an imperialist who would set his flag on every corner of the earth, he yet tears down no other flag and welcomes the invasion of his own territory by every science.

As I claim for psychology the freedom of the universe in its subject-matter, so I believe that every method of science can be used by the psychologist. The two great achievements of science have been the elaboration of the quantitative method on the one hand and of the genetic method on the other. The uniformity of nature and the rationality of things are here presented in their most convincing, or at all events most plausible form. It would be an irreparable limitation if either of these methods did not apply in psychology. In my opinion they not only do obtain but must obtain. The mental and the physical are so inextricably interfused that quantitative and genetic uniformities could not exist in the physical world if absent from consciousness. If our mental processes did not vary in number, if they did not have time, intensity and space relations, we should never have come to apply these categories in physics, chemistry or astronomy. I am not prepared to attempt to clear up the logical questions involved; when water is muddy it is often wise to wait for it to settle rather than to keep stirring it up.

Under the conditions of modern science nearly all observations are experiments and nearly all experiments are measurements. A sharp distinction is usually drawn between an experiment and an observation. Thus Wundt, following Mill and other logicians, defines an experiment as an observation connected with an intentional interference on the part of the observer in the rise and course of the phenomena observed. But it is as properly an experiment to alter the conditions of observation as to alter the course of the phenomena observed. If the astronomer

goes to the ends of the earth and photographs a solar eclipse, making all sorts of measurements and calculations, we may say that this is an observation and not an experiment, but we have not made a useful definition; neither do we gain anything by deciding whether it is an experiment when a baby pulls apart a doll to see what is inside. The real distinction is between the casual experimenting and observing of daily life, and the planned and purposive experiment and observation of science. Science is experimental *qua* science.

I consequently object to making experimental psychology a branch of psychology. It is a method in psychology, which is extended just as rapidly as psychology becomes a science. The purely introspective or analytic observer does, according to the current definition, continually make experiments, because his introspection itself alters the process that he is observing, thus sometimes making his observations invalid as a description of natural conditions. On the other hand, the student in the laboratory may measure the process without any introspection or interference with it, and this may not be technically an experiment at all, but it gives a scientific description of the normal course of mental life. We are told that Adam gave a very appropriate name to the hog; science is not always so fortunate in its nomenclature.

Most experiments, letting experiments mean attempts to increase scientific knowledge, are also measurements. Measurement is only a description; but it has proved itself to be the most economical, wide-reaching and useful form of description. What language was for the evolution of primitive man, measurement is for the advance of modern science. As a word selects similarities and ignores differences, so a measurement selects certain similarities from the concrete manifoldness of things. That such a great part of the world can be described in terms of a few units of measurement, and that this description should lead to such useful applications, is truly marvelous and admirable. As I am writing these paragraphs, I have received a manuscript in which the author explains that the fact that the earth rotates on its axis in twenty-four hours, not varying a second from day to day, is a conclusive proof that it was created and set rotating by a benevolent being. If the days were shorter, he says, we could not get our work done, and if the days were longer, we should be too tired by night. It almost seems as though the world were made in such comparatively rational fashion in order that we may measure it.

The physicist counts, and he measures time, space and energy. He has intractable matter with its seven and seventy elements, and he may come across a substance as complex and perplexing as radium. But by and large he can describe his world in certain quantitative formulas. It is true that he accomplishes this in part by unloading on psychology qualitative differences, such as colors and tones. So much the

more satisfaction to us if we can reduce them to quantitative order. Perhaps we shall have only partial success; but it may fairly be urged that psychology has done as much in this direction in fifty years as physics accomplished to the time of Galileo or chemistry to the time of Lavoisier.

The psychologist counts and he measures time, space and intensity. Even if it were true—I think it is not true—that mental magnitudes are not measurable, it would none the less be the case that mental processes are described in quantitative terms. This is attempted and accomplished in most of the researches published in our psychological journals. They describe measurements and the correlation of quantities; they show that a mental mechanics is more than a possibility.

The physical sciences have been primarily quantitative and the biological sciences are primarily genetic, but the physical sciences must become genetic and the biological sciences must become quantitative. Psychology is from the start both quantitative and genetic. It may indeed be claimed that it is the science in which the genetic method has the most complete application. Every mental state and every form of activity is the result of development from previous conditions. If explanation, as distinguished from description, is possible anywhere in science it is possible here. It is certainly difficult to penetrate by analogy into the consciousness of the lower animals, of savages and of children, but the study of their behavior has already yielded much and promises much more. Although those who make their psychology coterminous with introspection can not enter far into this field, they still have their own genetic problems. In whatever direction we turn the harvest is waiting; it is only the reapers who are few. Almost every observation, experiment or theory of organic evolution offers parallel problems for the psychologist. The development of the individual opens questions more numerous and more important for psychology than does the development of the body for other sciences. Senile, degenerative and pathological conditions are all there for psychological investigation. The evolution of society and the inter-relations of individuals are being gradually brought within the range of genetic psychology. It is quite possible that the chief scientific progress of the next fifty years will be in this direction.

The problems of psychology are certainly made endlessly complex by the fact that we have to do not with the development and condition of a single mind or individual, but with innumerable individuals. The traditional psychology has been disposed to ignore individual differences; but in attempting to prescribe conditions for all minds, it becomes schematic and somewhat barren. It is surely wasteful to select those uniformities that are true for all and to throw away those differences which are equally fit material for scientific treatment.

Linnæus instructed his pupils to attend to species and to ignore varieties, and this in the end tended to make systematic botany and zoology unfruitful. If the zoologist had limited his work to the discovery of facts that are true for all animals and had ignored the differences between animals, he would have done something analogous to what the psychologist has actually done.

It may be that individuals can not be grouped into species or even varieties, but animals and plants are separated into species in accordance with the noticeable differences between them, and there are as many degrees of just noticeable difference between men as between related species. We have in any case the different species of the animal series and the different races of men for psychological study; it may be that instincts and mental traits have specific or racial significance for the zoologist or anthropologist. We have the infant, the child, the adolescent and the aged; we have the two sexes; we have the geniuses, the feeble-minded, the criminals and the insane—complex groups to be sure, but open to psychological investigation. It may be that mental imagery or types of character will give workable groups. But even if mental traits and their manifestations are continuous, we can study the continuum. The study of distribution and correlation appears to open up subjects of great interest and having important practical applications.

The question of the practical applications of psychology is the last which I shall touch. There are those who hold that there is something particularly noble in art for art's sake or in science divorced from any possible application. We are told of the mathematician who boasted that his science was a virgin that had never been prostituted by being put to any use. It is doubtless true that science justifies itself if it satisfies mental needs. It may also be true that pure science should precede the applications of science. But of this I am not sure; it appears to me that the conditions are most healthful when science and its applications proceed hand in hand, as is now the case in engineering, electricity, chemistry, medicine, etc. If I did not believe that psychology affected conduct and could be applied in useful ways, I should regard my occupation as nearer to that of the professional chess-player or sword swallower than to that of the engineer or scientific physician.

It seems quite obvious that such knowledge as each of us has of his own perceptions, mental processes and motor responses and of the reactions and activities of others, is being continually used, more continually indeed than any other knowledge whatever. This knowledge is partly organized into reflexes and instincts; it is in part acquired by each individual. Control of the physical world is secondary to the control of ourselves and of our fellow men. The child must observe

and experiment to fit itself into the social order, and we are always experimenting on it and trying to make it different from what it is. All our systems of education, our churches, our legal systems, our governments and the rest are applied psychology. It may be at present pseudo-science, in the sense that we have drawn conclusions without adequate knowledge, but it is none the less the best we can do in the way of the application of systematized knowledge to the control of human nature.

It certainly is not essential and perhaps is not desirable for every mother, for every teacher, for every statesman, to study psychology, especially the kind of psychology at present available. It is not necessary for a man to be either a psychologist or a fool at forty; he may, for example, be both. But surely it is possible to discover whether or not it is desirable to feed a baby every time it cries, to whip a boy when he disobeys or to put a man in prison when he breaks a law. If each man were given the work he is most competent to do and were prepared for this work in the best way, the work of the world all the way from the highest manifestations of genius to the humblest daily labor would be more than doubled. I see no reason why the application of systematized knowledge to the control of human nature may not in the course of the present century accomplish results commensurate with the nineteenth century applications of physical science to the material world.

The present function of a physician, a lawyer, a clergyman, a teacher or a man of business is to a considerable extent that of an amateur psychologist. In the inevitable specialization of modern society, there will become increasing need of those who can be paid for expert psychological advice. We may have experts who will be trained in schools as large and well-equipped as our present schools of medicine, and their profession may become as useful and as honorable. Such a profession clearly offers an opportunity to the charlatan, but it is not the only profession open to him. For the present the psychological expert should doubtless be a member of one of the recognized professions who has the natural endowments, special training and definite knowledge of the conditions that will make his advice and assistance of value. But in the end there will be not only a science but also a profession of psychology.

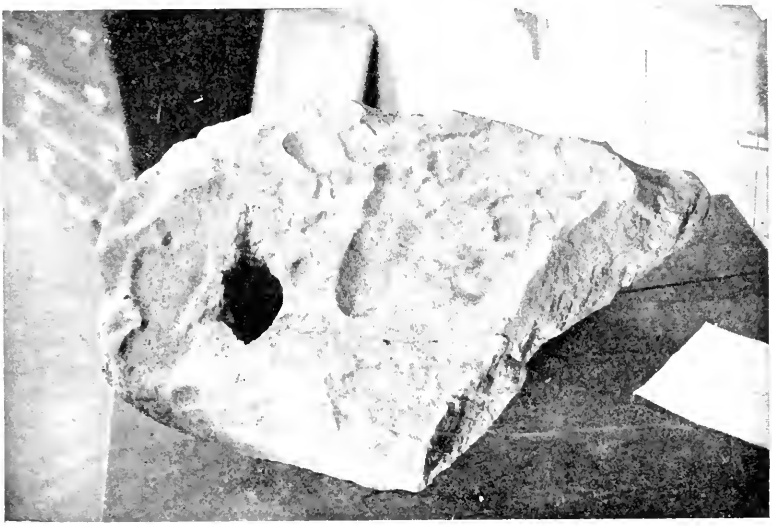
SHORTER ARTICLES AND DISCUSSION.

THE ANGEL STONE AT NEW HARMONY.

To the Editor: I enclose a photograph which represents an interesting human document. In the years from 1814 to 1825 Johann Rapp was leader and prophet of the religious sect of Harmonists located on the Wabash River, at New Harmony, Indiana. In 1825, the property of this community was purchased by the colony founded by Robert Owen and William Maclure, and the Harmonists under Rapp removed to their new home at Economy, Pennsylvania.

In both locations the community was financially very successful, while their more enlightened successors scattered in dissension within two years. The success of the community under Rapp's guidance was due to the fact that it was an absolute tyranny, theocratic in its claims, and that all farming and business operations were directed absolutely by one mind.

Rapp had a way of miraculously appearing in the harvest field and in similar places, seemingly springing out of the ground. This he did literally, for it is said his successors found a number of tunnels leading from his house outward and opening in unsuspected places. Among other forms of divine guidance, Rapp had a visit each morning from an angel, who came barefooted and stood before him on a large stone, giving him direction for the affairs of the day. This stone is still preserved. It was presented to the Museum of the University of Indiana by the late Professor Richard Owen, son of Robert Owen of Lanark, the founder of the second colony of New Harmony. This stone in Rapp's



The Angel Stone of the Rapp Community at New Harmony, Now in the Museum of Indiana University.

time showed clearly the prints of the angel's feet, and these, a little worn, are represented on the stone as it is preserved to-day. I owe the accompanying photograph of this stone to the courtesy of Professor Carl H. Eigenmann.

The stone suggests the sole condition under which communistic or socialistic organizations have been economically successful—that of complete subordination of the individual wills to the will of some one individual supposed to have mystic power or a divine commission.

David Starr Jordan.

DE MORGAN ON THE 'SHERMAN PRINCIPLE.'

To the Editor: Apropos of the papers which have recently appeared in the Popular Science Monthly and elsewhere dealing with the frequency distribution of word and sentence lengths in the writings of various authors, the following extract from a letter written by Professor De Morgan in 1851 is, I think, of some interest. The letter from which the extract is taken was written to the Rev. W. Heald, and is dated August 18, 1851. It is printed in the 'Memoir of Augustus De Morgan,' edited by his wife, Sophia Elizabeth De Morgan (pp. 214–216). After dealing with sundry other matters the letter proceeds in this way: "I wish you would do this: run your eye over any part of those of St. Paul's Epistles which begin with *παυλος*—the Greek, I mean—and without paying any attention to the meaning. Then do the same with the Epistle to the Hebrews, and try to balance in your own mind the question whether the latter does not deal in longer words than the former. It has always run in my head that a little expenditure of money would settle questions of authorship in this way. The best mode of explaining what I would try will be to put down the results I should *expect* as if I had tried them.

"Count a large number of words in Herodotus—say all the first book—and count all the letters; divide the second numbers by the first, giving the average number of letters to a word *in that book.*

"Do the same with the second book. I should expect a very close approximation. If Book I. gave 5.624 letters per word, it would not surprise me if Book II. gave 5.619. I judge by other things.

"But I should not wonder if the same result applied to two books of Thucydides gave, say, 5.713 and 5.728. That is to say, I should expect the slight differences between one writer and another to be well maintained against each other, and very well agreeing with themselves. If this fact were established there, if St. Paul's Epistles which begin with *παυλος* gave 5.428 and the Hebrews gave 5.516, for instance, I should feel quite sure that the *Greek* of the Hebrews (passing no verdict on whether Paul wrote in Hebrew and another translated) was not from the pen of Paul.

"If scholars knew the law of averages as well as mathematicians, it would be easy to raise a few hundred pounds to try this experiment on a grand scale. I would have Greek, Latin and English tried, and I should expect to find that one man writing on two different subjects agrees more nearly with himself than two different men writing on the same subject. Some of these days spurious writings will be detected by this test. Mind, I told you so. With kind regards to all your family, I remain, dear Heald,

"Yours sincerely,

A. De Morgan."

Comment regarding this remarkable anticipation of supposedly very modern ideas seems superfluous.

Raymond Pearl.

THE PROGRESS OF SCIENCE.

THE TWO HUNDREDTH ANNIVERSARY OF THE DEATH OF LOCKE.

JOHN LOCKE, who was born on August 29, 1632, died on October 28, 1704, a century before the death of Kant, and two centuries before that of Spencer. The two hundredth anniversary of Locke's death was commemorated by the British Academy, where papers by Professors Fraser and Sir William Pollock were read, and at Johns Hopkins University, where Principal C. Lloyd Morgan, Professor F. J. E. Woodbridge, Professor J. McBride Sterrett, Dr. Wm. T. Harris and Dr. William Osler made addresses. Locke ranks in eminence with his contemporary Leibnitz, who controverted his teaching, and with the sage of Königsberg, upon whom he was destined to exert a powerful influence, although Lockism and Kantism have come to mean almost diametrically opposite ways of regarding the world. The friend of Boyle and Newton, he was always interested in experimental science. As a student and practitioner of medicine, he was intimately associated with Sydenham, by whom he was frequently consulted.

Locke's education was in some respects unconventional and his life one of varied incident. Taught at home until his fourteenth year, he was sent for a time to public school, thence to Oxford, with which he was connected as a student or a lecturer successively in Greek, rhetoric and philosophy for many years. At one time he was dismissed by order of the king for alleged complicity in schemes against the crown, but he was already securely ensconced in Holland, where he became the recipient of the favor of William of Orange, under whom he resumed his residence in England after the great revolution. During the troublous times which preceded, he had been actively interested in business and particularly in political affairs, chiefly through his connection with the Earl of Shaftesbury, and had held important public offices. While living in the family of Shaftesbury, as physician, adviser and general literary and social factotum, he undertook the education of an only son of the household. He took an active part in the formation of the Colony of Carolina and at one time contemplated emigrating to America. Never strong, he especially suffered from poor health after middle life, yet he was always of a cheerful and sociable disposition. He was well on towards sixty when he began to publish the series of works which have made him famous. The products of mature reflection, each of his books was nevertheless called forth by some concrete situation and directed to a definite, practical end. This circumstance, together with their candor and common-sense and the freshness of their style, which is remarkably free from technicalities, early won for even the most obscure of his productions a favorable reception among all sorts of readers, and gave his writings a permanent place in literature.

The 'Essay concerning the Human Understanding,' his most important book, contains his philosophy of knowledge and his classic contributions to psychology. Philosophy before Locke had been highly metaphysical as to its problems, and dogmatic in its method. It took a fresh start under the criticism of Locke, who deliberately set himself the preliminary task of inquiring 'into the original, certainty and extent of human knowledge, to-

gether with the grounds of belief, opinion, and assent.' How do we come by our knowledge and what are its limits? These are the problems which Locke regarded as fundamental, and with which philosophy has been largely preoccupied since his time. Many of the difficulties which modern speculation has encountered owe their origin directly to the curious turn which Locke gave to the solution of these problems. By introspection he was led to affirm that the mind knows only its own ideas, whence subjective idealism was sure to ensue. In no case do we known things, but only ideas which somehow represent things, thought Locke. He denied the existence of innate ideas of any kind, insisting that all the mind's ideas are acquired afresh by

JOHN LOCKE.

each individual's experience. The mind is a *tabula rasa,* a perfect blank, to start with. Experience is, however, of two kinds, *viz.* 'sensation,' whereby ideas of the qualities of external objects are acquired, and 'reflection,' whereby the mind becomes aware of its own operations, *i. e.*, acquires ideas of them. But the mind is marvelously capable of transforming the ideas which experience supplies to it by combining the 'simple ideas,' which are the ultimate data of experience, into 'complex ideas,' by discriminating simple components in complex experiences, by comparison, abstraction, etc. Locke's psychology, which is subservient to his avowed purpose of discovering the origin and limits of knowledge, is rationally one-sided, and is now largely obsolete, but he abounds in observations and analyses of permanent value. He was the first to speak of the 'association of ideas,' although he made no general use of the conception.

Locke's views on education powerfully influenced Rousseau. Education has for its aim the development of 'a sound mind in a sound body.' Physical education is of prime importance, and should consist in a process of hardening the body to endurance, special attention being paid to exercise, fresh air, sleep, diet, clothing and the like. Intellectual and moral education should aim at the development of a virtuous character, a self-respecting and self-supporting English gentleman, wherefore sound morals, good manners and skill in some trade or handicraft were regarded as essential, and given a place above mere learning. Locke thought the schools of the time unfitted to provide this training, and recommended private tutorial instruction. The studies should be useful, should appeal to the natural interest and aptitude of the pupil, and in matters of morality the child's sense of honor should be relied upon, corporal punishment giving place to moral suasion.

Influential as a moralist, an economist, and the leader in many public reforms, Locke was preeminently a defender and expositor of liberty. In a time of religious bigotry he wrought famously and well for toleration, and his name will be forever enshrined in those doctrines of civil rights which molded the public sentiment that gave birth to the United States. Before Jefferson drafted the Declaration of Independence, Locke had declared that 'all men are naturally in a state of freedom, also of equality.'

Locke has been rightly called the 'intellectual ruler of the eighteenth century,' and while it would not be safe to say that he is the greatest of English philosophers, he is certainly the most characteristically English, and probably the most widely influential.

THE MONUMENT OF PASTEUR AT PARIS.

In France scientific men are not without honor in their own country. It is probable that the conditions are more satisfactory here, where scientific work is adequately supported both by the state and by private endowments, although the scientific worker is likely to be unknown outside his own circle. But reputation and fame have so long been regarded as the rewards of certain kinds of service that the homage paid in France to a man such as Pasteur may attract young men to a scientific career, even though it may not be a very important factor in stimulating their subsequent work. Monuments in memory of Pasteur have been erected in various parts of France. At Dôle, where he was born; at Arbois, where he lived as a child; at Marnes-la-Coquette and Vaucresson, where he lived in later years; at Besançon, Lille and Alais, whose silk-worm industries he saved; at Melun and Chartres, where he performed the same service for the cattle and sheep.

Pasteur's chief monument is indeed the Institute Pasteur, erected and en-

dowed in his life time by public subscription, and now containing his tomb. But there was recently unveiled at Paris a monument, of which an illustration is here reproduced from *La Nature*. The figure in marble is the last work of the eminent sculptor Falguière, who died before it was completed. Around the base are allegorical figures, humanity offering a child to be cured of the most dreaded disease, a shepherd relieved from all anxiety for his flock, and the like. The monument, for the erection of which about $70,000 was contributed by international subscription, was unveiled in the presence of the president of the republic and his cabinet, and commemorative addresses were made by those most competent to tell of the work of one of the greatest of men of science and of benefactors of his race.

MONUMENT OF PASTEUR.

PROFESSOR VAN'T HOFF.

IN 1895 the Prussian Academy of Sciences called Professor J. H. van't Hoff from the chair of chemistry at Amsterdam to Berlin. He was to receive a salary and a laboratory and was to have no duties other than those which he might choose to assume. In

order that van't Hoff might lecture if he wished, he was appointed to a professorship at the University of Berlin, also without specified duties. The remarkable feature of this arrangement is that it was primarily as a member of the Academy that van't Hoff went to Berlin. No such honor has been paid a man in Germany since the time of Frederick the Great. An outline of van't Hoff's career will prove that the tribute was deserved.

When only twenty-two years old van't Hoff showed that certain unexplained cases of isomerism would be accounted for if structure formulas were so written as to represent the arrangement of atoms in space and not merely relations in a plane. The importance of this new point of view lay in the fact that it enabled chemists to classify substances which rotate the plane of polarized light and to predict what substances will possess this property. The branch of chemistry known as stereochemistry is the outgrowth of the paper published by van't Hoff in 1874 and of the independent statement of the same idea by LeBel a few months later.

In 1878 van't Hoff was appointed professor of chemistry, mineralogy and geology at the new University of Amsterdam. From this time forward his work has been in physical chemistry rather than in organic chemistry. In the next six years he rediscovered the law of mass action; he worked out the generalized theory of reaction velocities; he showed that the quantitative relation between chemical affinity and heat effect has the same form as the relation between electrical energy and heat effect deduced by Helmholtz. In addition to this he established the theorem which bears his name, on the quantitative displacement of equilibrium with change of temperature.

In 1885 a new period begins. Some experiments by the botanist, Pfeffer, were the starting-point. Pfeffer had been studying the rise of sap in trees and had found that a high pressure is necessary to prevent the diffusion of water through a membrane of colloidal copper ferrocyanide into a solution of sugar in water. Van't Hoff showed that the results of Pfeffer could be predicted if it were assumed that a dissolved substance exercises an osmotic pressure equal to the pressure which it would exert if converted completely into a gas occupying the volume of the solution and having the same temperature. This assumption not only explained Pfeffer's results; but also those of Raoult on the vapor-pressures, boiling-points and freezing-points of solutions. When the osmotic pressure theory of solutions was supplemented by Arrhenius's theory of electrolytic dissociation, it needed only the energy and enthusiasm of Ostwald to raise physical chemistry in the short space of twenty years to the position which it now holds.

In 1894 van't Hoff was offered the chair of physics at Berlin, made vacant by the death of Kundt. This was declined; but the ideal position offered by the Prussian Academy in the following year was accepted and van't Hoff left Amsterdam in 1896 for Berlin. Since that time he has worked systematically at a problem which had interested him off and on for many years previously. What this problem is can be learned from van't Hoff's own outline of his plans in an address before the Prussian Academy on July 2, 1896.

"The line along which I shall work is clear; the application of mathematics to chemistry remains my chief aim, and each opportunity to promote this in my new surroundings will be welcome. For the present, therefore, I shall devote myself to that portion of physical chemistry which deals with the so-called inversion phenomena, with the formation of double salts, and with double decomposition. The application of mathematics is possible in this field and there is the fascinating prospect of applications to the Stassfurt industry and to geology.

"I do not need to state that industrial applications will not be the object of the work. I have left my native land because I know that in Germany, more than elsewhere, we find widespread the conviction that the pursuit of knowledge for its own sake is the highest aim of human efforts."

PROFESSOR J. H. VAN'T HOFF, BERLIN.

The special form of the problem was a systematic study of the conditions of equilibrium in their bearing on the salt deposits at Stassfurt, but the general results are applicable to all cases in which the deposits consist chiefly of any mixtures of the chlorides and sulphates of sodium, potassium, magnesium and calcium. Although not yet finished, the work is a masterpiece and shows what can be expected from an application of physical chemistry to geology and mineralogy.

The work of van't Hoff can be divided crudely into four parts: 1872–1877, organic chemistry; 1878–1884, chemical affinity; 1885–1895, theory of solutions; 1896–1904, oceanic deposits. Much of the organic chemistry of to-day is the direct outcome of the work done in the first period; the second and third periods made physical chemistry

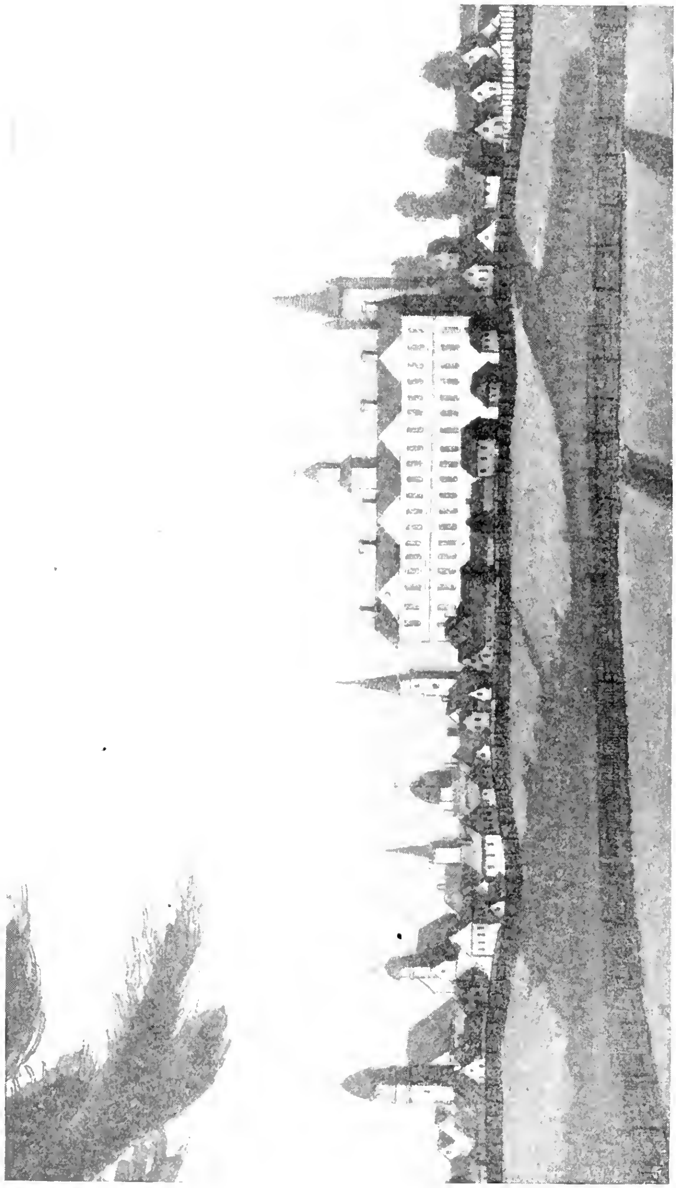
possible; the fourth period has probably introduced a new era in geology, of which the geophysical laboratory at Washington is a sign. It was because van't Hoff is a great exponent both of organic chemistry and of physical chemistry that he was the first man to be awarded the Nobel prize in chemistry. A man who commands the whole field of chemistry and who is deemed able to fill the chair of physics at the University of Berlin as successor to Kundt is a man who is well worthy of the exceptional honor paid by the Prussian Academy of Sciences to van't Hoff.

THE HUNDRED AND FIFTIETH ANNIVERSARY OF COLUMBIA UNIVERSITY.

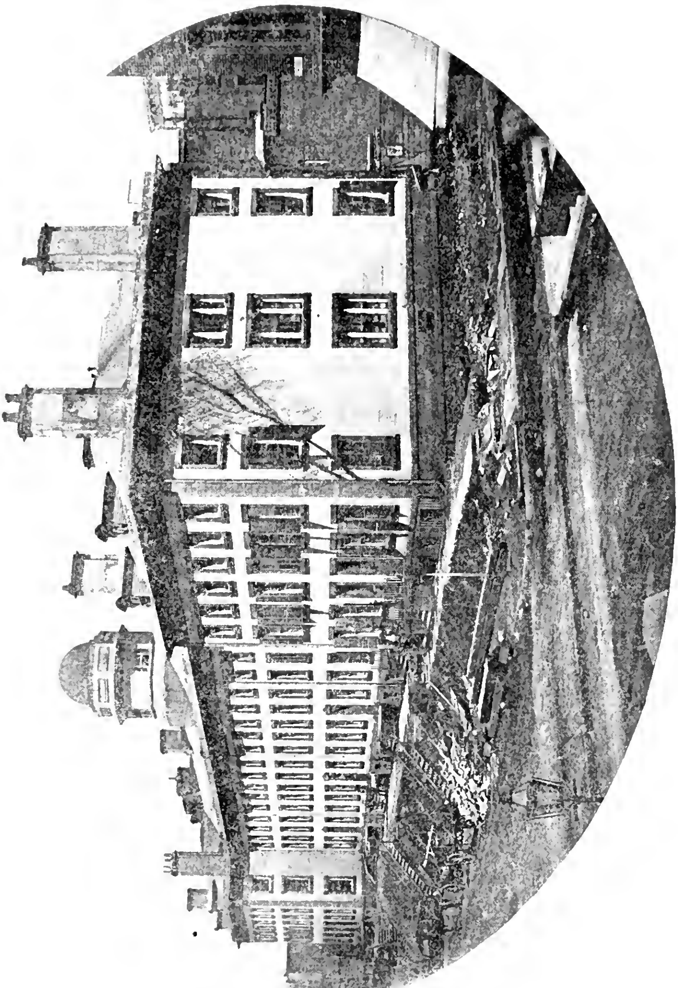
Columbia University, which received its charter as King's College in 1754, appears to be the sixth in age of American Colleges, having been preceded by Harvard (1636), William and Mary (1692), Yale (1701), Pennsylvania (1740) and Princeton (1746). Our universities are young in comparison with European institutions, whose obscure beginnings go far back into the medieval period; but it may be called to mind that the University of Berlin was founded in 1809 and the University of London in 1836. Our colleges were, indeed, established early in the history of the settlements, New York having been a trading village of less than 15,000 inhabitants when 'a public lottery was authorized to raise money for the advancement of learning and towards the founding of a college.' The first president, Samuel Johnson, in the announcement issued in 1754, offered an ambitious if somewhat vague program of studies. He proposed "to instruct and perfect the Youth in the Learned Languages, and in the Arts of *reasoning* exactly, of *writing* correctly, and *speaking* eloquently; and in the Arts of *numbering* and *measuring*: of *Surveying* and *Navigation*, of *Geography* and *History*; of *Husbandry*, *Commerce* and *Government*, and in the Knowledge of *all Nature* in the *Heavens* above us, and in the *Air*, *Water* and *Earth* around us, and the various kinds of *Meteors*, *Stones*, *Mines* and *Minerals*, *Plants* and *Animals*, and of every Thing *useful* for the Comfort, the Convenience and Elegance of Life, in the chief *Manufactures* relating to any of these Things." Dr. Johnson being the entire faculty until his son was added, it may be assumed that the actual course was limited to 'the learned languages' and elementary mathematics. The first professorship, however, was in mathematics and natural philosophy, established in 1757, when Dr. Johnson, in accordance with the original agreement, 'retired to some place of safety out of town when the smallpox prevailed.'

Columbia was a comparatively small institution until about 1860, but it has taken a leading part in the development of scientific education. A medical school was established in 1767, two years after the first American school had been founded in Philadelphia. In 1864 was established the School of Mines, the first institution of the kind in the country. In the small faculty of the college have been a considerable number of prominent scientific men, including Bard, Hosack, Mitchill, Adrian, Torrey, Newberry, Egleston and Rood. Barnard, president from 1864 to 1889, was a scientific man of eminence, who had broad ideas on education. After President Low's inauguration in 1890, a notable development followed, not least evident in the enlargement of the scientific departments, and this development continues under the administration of President Butler. Columbia now stands in the small group of the leading universities of the world, both in number of students and in contributions to the advancement of knowledge. It has earned the right to celebrate with satisfaction its one hundred and fiftieth anniversary.

The exercises were scarcely so elaborate as the Princeton sesquicentenial and the Yale bi-centenial. A large reception to the alumni was given by the



KING'S COLLEGE IN 1760



COLUMBIA COLLEGE IN 1857

(From a daguerreotype reproduced in the *Photographic and Fine Art Journal*, June, 1857)

trustees on October 28. On October 31 there was a university convocation, when President Butler made a commemorative oration and degrees were conferred on distinguished alumni. There was a banquet of the alumni in the evening and various other gatherings. Perhaps the most interesting event, as witnessing the continual growth of the university, was the dedication of the building for physical education of Teachers College, erected and furnished at a cost of $400,000 and the laying of the cornerstones of a chapel, of a school of mines building and of two dormitories. The school of mines is built in the same general style as the four buildings for the sciences already erected. The dormitories must be adjusted to a city environment, where land is expensive, the two city blocks on the side of which they stand having cost $2,000,000. In connection with the celebrations, there has been published by the Columbia Press a history of the university prepared by Dean Van Amringe and other authorities, which is a work of interest not only to alumni, but also to all who are concerned with the history of higher education in the United States.

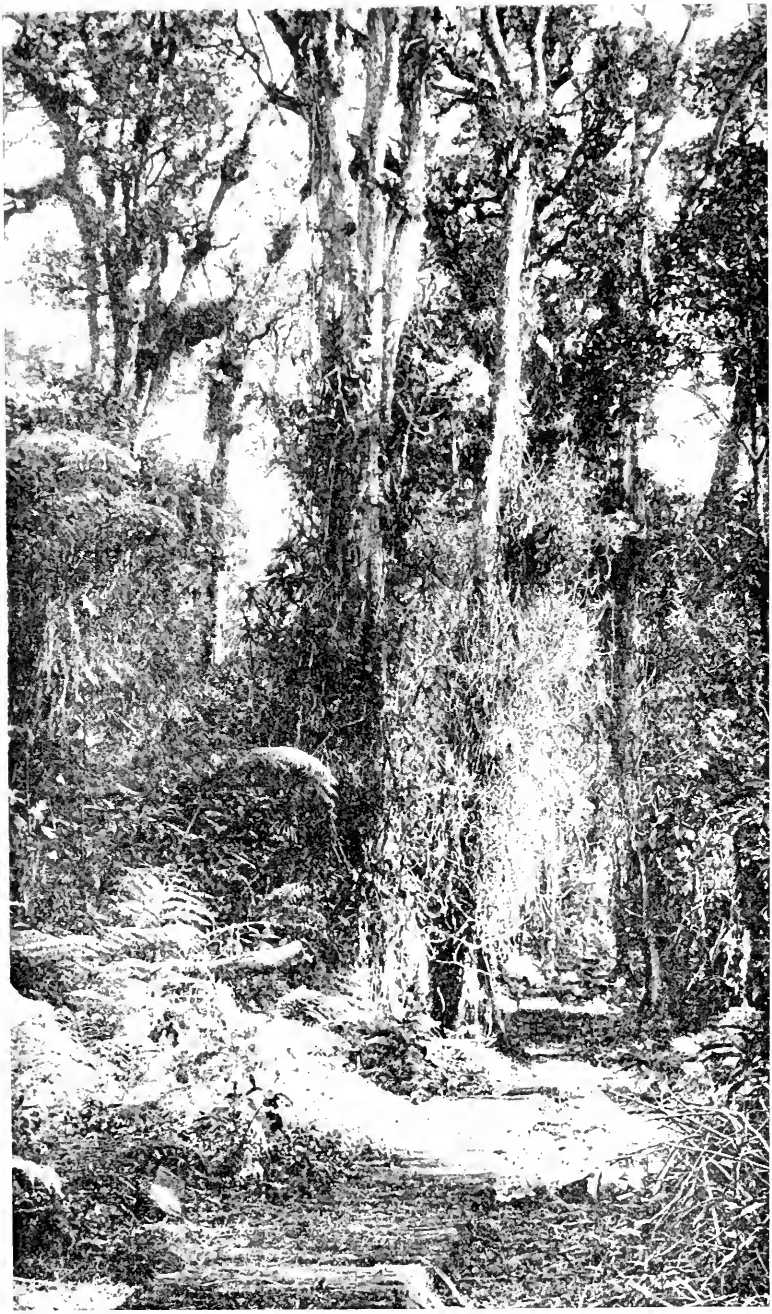
THE FORESTS OF THE HAWAIIAN ISLANDS.

Mr. William L. Hall, in charge of forest extension of the Bureau of Forestry, has drawn up a report on the forests of the Hawaiian Islands which is of some general interest. The forests are of two entirely different kinds, which in no case meet. Those near the sea-level consist of a single species, now covering at least fifty thousand acres, all of which sprang from a single algaroba tree, which grew from a seed planted in 1837. These forests have considerable economic value. They supply cord wood and posts, and live stock feed on the pods. The land occupied by these trees is mostly worthless for any other purpose; they are so hardy and so fully appreciated by the people that they will be cared for without any special action on the part of the government.

The conditions are different in the case of the native forests, which cover or formerly covered the mountains of the islands. These forests, which consist of lehua, koa and other native trees are tropical in character, containing none of the familiar trees of the north temperate zone. The trees are not very valuable commercially, but the forests themselves are said to be of the utmost value in conserving the water supply of the islands. There is an abundant and luxuriant undergrowth with a great quantity of humus, possessing an enormous capacity for holding water. When the forests are cleared, either purposely or by accident, there is danger that there will not be enough water conserved to supply the sugar plantations. These supply the chief industry of the islands, the exports of sugar being valued at some $25,000,000, ninety-six per cent. of the total exports of the islands. The forests have in part been destroyed in a curious way. Cattle were introduced into the islands in the eighteenth century and were turned out to run at large. They trampled down and ate the undergrowth, without which the ground dries up and the shallow-rooted trees die. Goats, pigs and deer also run wild in the forests. In view of the conditions cooperation of some character is essential, and the people of Hawaii have through their legislature passed a bill creating a forest reservation, and appropriating $28,000 annually for its support. A trained forester has been appointed, and the work is being carried forward with the cooperation of the Division of Forestry of the Department of Agriculture.

SCIENTIFIC ITEMS.

Professor Clemens A. Winckler, the eminent chemist, died at Dresden on October 8, at the age of sixty-six years.—Professor Nils Finssen, of Copenhagen, known for his discovery of the light cure for lupus, died on Sep-



INTERIOR OF LEHUA FOREST.

tember 24. A committee has been formed to collect a fund for the erection of a monument.—Professor Max Bartels, of Berlin, known for his publications on ethnology, died on October 22, at the age of sixty-two years.—Major Henry F. Alvord, chief of the dairy division of the United States Department of Agriculture, died at St. Louis on October 1, as the result of a stroke of paralysis.

Professor Simon Newcomb has been elected a corresponding member of the Vienna Academy of Sciences.—The medal of the Society of Chemical Industry, awarded every second year for services to applied chemistry, has been presented to Dr. Ira Remsen, president of the Johns Hopkins University.—It is reported that the Nobel prize for medicine will this year be awarded to Dr. Robert Koch. He has been presented with a portrait bust and a *Festschrift* on the occasion of his sixtieth birthday.—Columbia University has conferred the degree of D.Sc. on Sir William Ramsay, the retiring president, and on Mr. W. H. Nichols, the president-elect, of the Society of Chemical Industry.—A memorial tablet to Dr. Jesse Lazear, who died in Cuba in 1900 while investigating the causes of yellow fever, has been unveiled at the new surgical building of the Johns Hopkins Hospital.—King Edward has directed that a new medal be struck for service in polar regions. The officers and crew of the Antarctic exploration ship *Discovery* will be the first recipients of the medal.

The St. Petersburg Institute of Experimental Medicine has sent an expedition to the shores of the Black Sea to inquire into the prevalence of malaria, especially in the neighborhood of Gagory.—The Liverpool School of Tropical Medicine proposes to despatch a second yellow fever expedition to the Amazon in view of the necessity of investigating still further this malady. The late Dr. Walter Myers was selected by the school, together with Dr. Herbert Durham, to undertake an expedition to Para to investigate the disease, only a few years ago. Both members of the expedition were attacked by the malady and Dr. Myers died. The expedition will probably start at the end of the year.—Professor Robert Koch has recently returned from Detmond, where he was engaged in investigating an outbreak of typhoid fever for the German government, and has since been at Paris, where he was entertained by the Pasteur Institute. In the course of the winter he will proceed to German East Africa in order to continue those studies of tropical and other diseases which he had not completed during his recent visit to Rhodesia. In particular he will continue to investigate the part played by ticks in conveying the infection of various cattle diseases.

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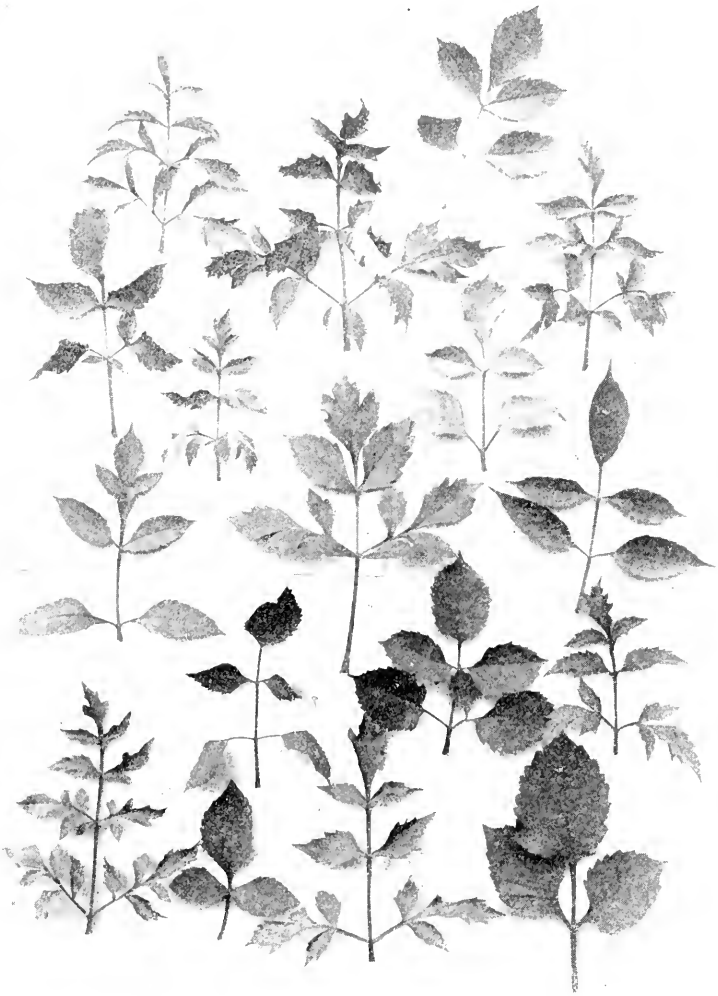
SOME EXPERIMENTS OF LUTHER BURBANK.

BY PRESIDENT DAVID STARR JORDAN,
LELAND STANFORD JUNIOR UNIVERSITY.

MR. LUTHER BURBANK, of Santa Rosa, California, is doubtless the most skilful experimenter in the field of the formation of new forms of plant life by the process of crossing and selection. He is the creator of many of our most useful plant forms: roots, nuts, fruits, grains and grasses, as well as of many of our most beautiful flowers. His methods are the practical application of the theories of Darwin and his followers, and to a degree wholly exceptional among plant breeders, Mr. Burbank has kept in touch with most modern work in the field of bionomics, and very much of his time and energy is devoted to experiments of scientific interest not likely of themselves to yield immediate practical results. In the nature of things, the demands of his work, and the necessity for the sale of new forms produced by him, have prevented the keeping of detailed records of his work, although steps have been taken toward the provision of explicit records in the future. For the rest, Mr. Burbank's success in practical achievement gives weight to his views on theoretical questions.

The present writer has recently at different times spent three days in Mr. Burbank's company at his gardens at Santa Rosa and Sebastopol, keeping note of things seen and of Mr. Burbank's views concerning them. In this paper, selections are made from these notes, the forms of plants referred to having been examined by the writer and the report of explanations having been verified by Mr. Burbank. All quotation marks refer to conversations with Mr. Burbank, the statement of which Mr. Burbank has verified or corrected. The accompanying illustrations are all from photographs by Mr. Burbank.



SAMPLE LEAVES OF COMMON GARDEN DAHLIA (*Dahlia variabilis*), SHOWING ORDINARY VARIATION *within* A SPECIES WHEN UNDER CULTIVATION.

The process of formation of new types may be grouped under four heads: selection, crossing, hybridization and mutation (or saltation). The process of artificial selection is used in all cases, those varying strains likely to prove useful being preserved, the others destroyed. The word 'crossing' may be advantageously used for the mingling of strains within a species, and 'hybridization' for the breeding together of members of different species. The name 'mutation' (or preferably 'saltation') is applied to sudden changes of characters for which no immediate cause is apparent.

Not many of Mr. Burbank's results are due to unassisted selection, as the processes of crossing and hybridization save time by the increase of the rate or degree of variation. There is, however, no evident limit to the results to be obtained by simple selection. New and permanent species of wheat have, without a shadow of doubt, been produced by selection alone.

In the California poppy (*Eschscholtzia californica*), stripes of crimson are never seen on the inside. Mr. Burbank once found a seedling in which the outside crimson had struck through like a crimson thread which had been misplaced. In other generations, by selection, this red was more and more increased, until finally out of it is developed a crimson poppy, of which Mr. Burbank has now many specimens, seeding more or less true to the type. The 'Shirley' poppy (*Papaver rhœas*) is well on the way to blue by selection.

It is questioned whether competition in minor details, or 'intra-specific selection,' can form species permanent as wild species are. As to this, Mr. Burbank notes that the cultivated species produced after the fashion of his crimson eschscholtzia 'have a very brief history compared with the wild species, and, moreover, they are constantly being placed in a new environment by man, being influenced by new soils, new climates, new fertilizers and the like.' "Breeding to a *fixed line* will bring fixed results. Man's desultory breeding is brief, the struggle for existence is mostly absent, and new ideals and new uses are required instead of ability to endure under natural conditions. Man's efforts at selective breeding are fluctuating, with frequent saltations."

Dr. De Vries notes that in the common sugar beet, which is a biennial species, there are from one to ten per cent. of plants which bear seed the first year. None of these is ever chosen for seed, and yet the long-continued process of natural selection has never succeeded in rooting them out. As to this Mr. Burbank observes: "This long-fixed tendency to insure continued existence in the past is not yet bred out. Analogous to this is the tendency in flocks to produce black sheep, and the appearance of zebra stripes on horses—ancestral traits not yet bred out."

From the pale yellow Iceland poppy (*Papaver nudicaule*) are developed white, yellow and orange forms, and some with striped petals and a strong tendency to become double. Selecting the Iceland poppy for size alone, flowers three and one-half inches across have been developed. A large scarlet poppy, *Papaver glaucum*, closes its two inner petals when a bee or two have entered, shutting in the bees, which buzz angrily and cover themselves with pollen until they are set free. If not visited by bees, the flowers *do not close*.

A wild form of one of the Liliaceæ, *Brodiæa terrestris*, was made white by selection of the palest among the pale wild ones. *Brodiæa*

lactea taken from the high Sierras where it is a dwarf, becomes, after two years of cultivation, more than twice as high as the original stock, but not nearly as high as the same species grown in the valley.

"Crossing is done to secure a wealth of variation. By this means we get the species into a state of perturbation or 'wabble,' and take advantage of the 'wabbling' to guide the life forces into the desired habits or channels. The first crossing is generally a step in the direction in which we are going, but repeated crossing is often necessary and judicious selection always necessary to secure valuable practical results. Crossing may give the best or the worst qualities of the parent, or any other qualities; and previous crossings often affect the results."

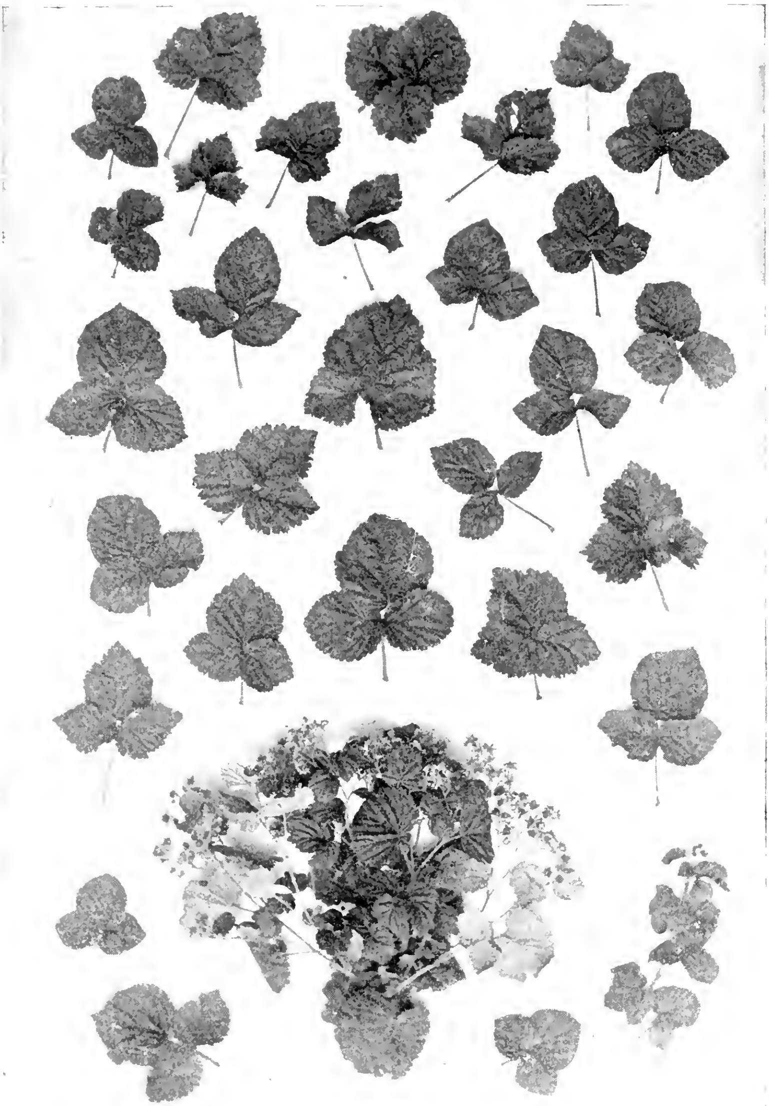
Primus, THE FIRST FIXED RUBUS SPECIES ARTIFICIALLY PRODUCED.

"Hybridization differs from ordinary crossing only in degree. A species is only a race which has assumed greater fixity. The purposes and results of crossing within the species and of hybridization of different species are essentially alike. The formation of the new individual by the sexual relation of two parents is in itself a species of crossing, giving each new individual in its degree new traits or new combinations."

"Bees and other insects, as well as the wind, cross plants, but they do not work intelligently, therefore rarely to any advantage economically to man. No mechanic could invent such devices as those which tend to prevent self-crossing in plants. *All evolution and improvement are dependent on crossing*, therefore nature has produced more wonderful devices for this purpose than for any other."

"Mutations, or saltations, are often found; that is, fixed forms springing up, generally from unknown causes, forms which are not hybrids, and which remain constant; as, for instance, colored flowers which yield white forms, these yielding white constantly in their progeny. *These mutations can be produced at will* by any of the various means which disturb the habits of the plant. It comes out when the conditions are ripe. New conditions bring out latent traits. I should expect mutations to arise in the American primrose and most other plants under wholly new conditions. Extra food or growth force as well as crossing favors variation, as does abrupt change of conditions of any kind. Five or six generations will usually fix a mutation. Sometimes it is fixed at once."

"On the average, perhaps about six generations fairly fix a variation, but this varies greatly, depending upon previously acquired hereditary tendencies. Bringing a species into a new environment dis-



LEAVES SHOWING A NUMBER OF STRAWBERRY-RASPBERRY HYBRIDS AND A CLUSTER OF THE BLOSSOMS.

turbs its fixity. Rich soil especially gives rise to variations in growth which seem to be new, and by repetition become inherently fixed. Sometimes ancestral states are brought about by good soil; sometimes

(perhaps oftener), also, by starvation; *new* variations oftenest by rich soil and general prosperity. *There is no evidence of any limit in the production of variation through artificial selection, especially if preceded by crossing.* Mutations are probably due to the sudden appearance of latent tendencies in new combinations, producing novel effects analogous to new chemical combinations."

"*Mutation is not a period, but a state* induced by various hereditary and external conditions. It is not by any means certain that there is any period in the life-history of the species when it is more subject to mutation than at other times, other conditions being similar. By crossing different species we can form more variations and mutations in half-a-dozen generations than will be developed by ordinary variation in a hundred or even a thousand generations."

"The La France and some other roses, as well as dahlias, callas and many other plants, every once in a while throw out, on some particular year, a number of unusual sports in various localities. This is probably a matter of season, the forces outside bringing about parallel mutations. The evolution of species is largely dependent on crossing the variations contained within it. Forms too closely bred soon run out, because generally only by crossing does variation appear. It is of great advantage to have the parents a certain distance apart in their hereditary tendencies. If too close together there is not range enough of variety. If too far apart, the developed forms are unfitted for existence because too unstable. *Correlated changes work together to produce the effect of mutations.* Environment effects a permanent change in species by selection of those which fit it or by producing changes in individuals which are better equipped to survive. *Heredity is the sum of all past environment,* conditions both latent and apparent. Latent traits often arise when circumstances make them possible. Environment of a lifetime does not necessarily or usually appear in another lifetime, but *continues in the same direction* and will strike into the nature of the plant in time. We may refer to Emerson's remark on the 'baking into the picture of the pigment laid down by environment.' Selection is 'cumulative environment.' Fortuitous variations occur everywhere. They come up all the time, from past environments, past heredity and present opportunity. No two individuals are alike. Where there is a marked tendency in one direction, we have the case of a persistent effect of environment. Monstrosities are engorgements of force. They are generally a thousand times more likely to develop another sort of monstrosity than normal individuals are. You are likely to get from sports and monstrosities either extreme of variance. *They do not, however, maintain themselves, because heredity pulls back their descendants.* A wide variance is more easily pulled back than a slight variance. There are cases where the monstrosity might pull back its species.

This is more likely to happen if the forces of natural or artificial selection were in its favor. There are many cases where the variant in minor points is prepotent and outweighs the original stock. Monstrosities produced by crossing often perpetuate themselves as well as the species does."

"One difficulty with the mutation theory of Dr. De Vries, in my opinion, is lack of sufficiently wide experimentation. Fuller investigations will certainly show that the 'sports' or 'chance' variations come under the same law as that of 'fluctuating' variations, mutations being only fluctuating variations carried beyond the critical point where past fluctuating variations can not withstand the accumulated forces without disintegration, thus bending them in a new direction."

"Professor Hubrecht is certainly in error in stating that the mean fluctuations can not be carried into the extreme or 'sport' variations by selection. Professor Hubrecht speaks of two divergent processes, 'fluctuating variations' and 'mutations,' which he says: 'Darwin has not sufficiently kept separate.' They are not separate; one is only a tendency toward the other, and which continued, though latent, may, or will, at last become dominant, so as to swing the fluctuating variations fully out of the old orbit into the 'mutation' or 'sport' condition. Radical changes of environment for a series of generations will produce a tendency to sport, but hybridization will bring it about far more abruptly, and for practical plant or animal breeding or for scientific study of all these variations, far more satisfactorily."

"The misunderstanding evidently comes from not having a clear knowledge of latent and dominant hereditary forces. A knowledge of these explains the whole matter and makes harmony between Darwin and Wallace, leaving Professor De Vries's careful experiments good, but coming to different conclusions on the results."

"Professor Hubrecht also states that 'now for the first time—forty years after the appearance of the 'Origin of Species'—the actual birth of a species has been observed by him.' As I have produced several good species by hybridization, as good as nature herself has produced, and as others have done the same by selection alone, the above sentence is hardly true. But as before stated, hybridization followed by selection is the shortest plan by which valid new species can be produced. In other words, the *'period of mutation' can be produced at will!*"

"The mutation theory of the origin of species seems like a step backward towards the special creation theory, and without any facts as yet adequate to support it as a universal theory, however valuable and suggestive the experiments of Dr. De Vries may be."

"There is a remarkably close analogy between hybridization and grafting. Bringing over from France a prunus (*P. mirobolana* var.

pissadi), of which there was no other specimen in America, it was grafted on to the Kelsey plum, a variety of *Prunus triflorus.* The graft itself did not bloom, but the presence of the graft brought about in the tree a cross of the two species. This is the only case known to me in which the graft affected the reproductive system of the plant, forming a cross between forms which had never crossed. Many hundred descendants of this cross are now living. Darwin accepted with reservations the account of the graft hybrids in potatoes, and there still remains some doubt of reliable testimony of the supposed fact. He also speaks of a now well-known graft hybrid of a yellow and purple cytisus, which is perhaps the most remarkable fact in this line on record."

DIAGRAM SHOWING THE ZONE OF LIFE AND PARALLELISM OF RESULTS IN CROSSING AND GRAFTING. (L. B.)

Utter refusal to unite under any circumstances, either by crossing or grafting. (Outside of zone of possible union.)

Crossing by Seeds.		Crossing by Graft.
Pollen acts as a poison.		Grafts blight and die as if poisoned.
Union partial, mosaic or temporary; seed rarely produced; seedlings generally inherit tendencies and qualities of one parent only; second or later generations revert fully.		Grafts often form a temporary union but are not in a normal condition. Avoided by nurserymen and planters with great care, as results are often disastrous to the grower.
Union free; seedlings show unbalanced condition, varying widely; often unusually vigorous; best condition for scientific or natural selection. Good qualities can be made permanent to the race.	Mendelian or Mutative State.	Grafts unite readily but separate under unusual stress—drought, overbearing, lack of nourishment, etc. Avoided by nurserymen and planters.
Unite freely; seed of superior germinating quality produced abundantly. Seedlings normal with ordinary amount of variability.	Unusual Variation.	Grafts unite readily, thriving well; sometimes better than when grafted on their own stock.
Ordinary plant life as oftenest met with.	Normal.	Grafts unite and thrive as we oftenest see them.
Self-fertile; seed produced, but as there are very limited opportunities for profitable variations, this state ultimately ends in		Grafts grow on their own roots.

EXTINCTION.

All these varying states shade off from one to the other, with few hard and fast lines of separation.

"In some directions the strains of heredity are much more unbalanced than in others. An impulse from outside forces may bring about new combinations. This is illustrated by De Vries by a ball with many facets, which, if lightly touched, will return to its original position, if vigorously touched will turn over. Burbank once crossed a pole bean (*Phaseolus vulgaris*) with a lima bean (*Phaseolus lunatus* var. *macrocarpus*). There was no visible effect in the appearance of the pod or the bean, but, when planted, each bean developed a cotyledon, part of one species and part of the other. The lima bean represented the end of the cotyledon, and was united to the lower part by serrated edges; below was the smaller and striped cotyledon of the pole bean. The cotyledons finally parted at the joints between the two, the upper portion falling off, as is often the case with grafts which are uncongenial. The forms were tremendously vigorous, but all came back to the common pole or horticultural bean after the second generation, as though it were an uncongenial graft hybrid, the alien portion being finally entirely rejected. It often happens in grafting, that the branch will be united thoroughly at the point of grafting, but in great stress, as the overbearing of fruit, the grafted portion will separate and entirely fall off."

"In one sense, hybridization is only a mode of grafting, both being a more or less permanent combination. The different results from hybridization are shown in the diagram below."

"Where the plants are very different, having a different line of descent, and consequently different structure, there will be no hybridization at all. From this we have every gradation to the point where the individuals are very closely alike, and here we have scarcely any variation at all in the progeny, a condition which favors extinction. Again, in grafting, we have every intergradation between total inability to unite and absolutely perfect blend."

"Sometimes a graft strengthens a plant by increasing the body of foliage and thus strengthening the roots. Grafting a Japanese pear on the Bartlett pear will give the latter new life through the increase in the foliage, which gives material for root action and further extension."

As illustrations of the results of crossing and hybridization, the following notes were taken on plants in Mr. Burbank's gardens:

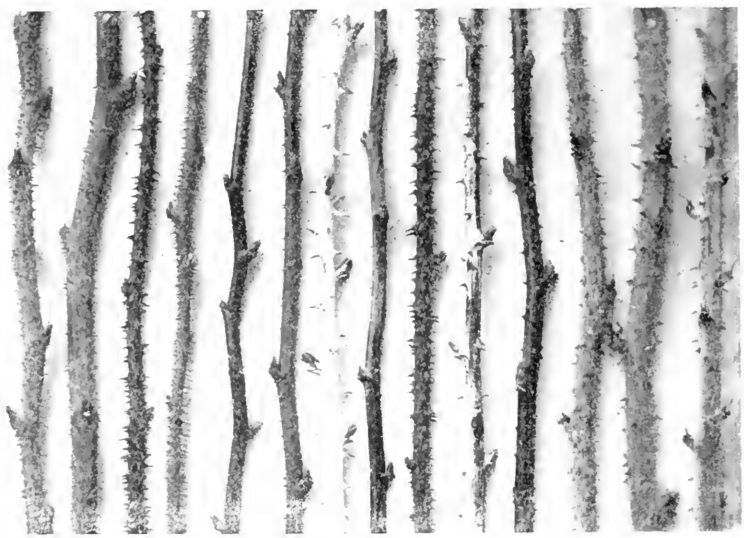
In the beginning of his work Mr. Burbank crossed all sorts of beans and had a half acre of them. Some climbed to the height of twenty or thirty feet, producing all sorts of pods—some with pods long and slender and stems so short that the pods doubled up on the ground. These forms could have been fixed in time, though the variations were unusually persistent and very amazing in their variety and abundance.

Crossing the red and white pole bean, two or three of the beans grew large and bore striped pods, the beans themselves being jet black.

From this cross many varieties were developed having all the colors known in beans.

The results of selection are often so simple as to form a mathematical rule, as in the case of Mendel's peas, which holds good with the tribe of peas (*Pisum*), but not generally with others so far experimented on. At other times they are so complicated that to follow them requires the highest skill, or may be utterly impossible.

A rubus (*R. cratægifolius*) from Siberia has fruit the size of a large half pea, brownish, seedy and tasteless. Hybridizing with the California blackberry (*R. vitifolius*), some of the hybrids have the best qualities of both berries combined, and a perfect balance of characters. Out of over five thousand second generation hybrid seedlings, every one is true to the seed. This refers to the Primus blackberry, which is now fully as true a species as any classified species of *Rubus*.



Stems of Blackberry-Raspberry Hybrids.

The raspberry has been hybridized with a strawberry: the results were thornless plants with trifoliate leaves looking like a strawberry plant and sending out underground stolons like the strawberry. At last, however, the plants send up canes three to five feet high bearing panicles of flowers more profuse in number than those on either parent. After flowering the plant never produces a berry, the fruit forming a small knob, with no effort at maturity.

In the hybrid of the strawberry and raspberry, the resultant plants bore three or four times as many flowers as the raspberry, seven or eight times as many as the strawberry.

Tendencies strong in the parent, even though for a time latent,

Leaves of Blackberry-Raspberry Hybrids.

usually come out strong in the descendants. Ordinary hybrids of forms closely related generally form a perfect blend from both parents. When the parents are far apart all sorts of variations occur, the so-called Mendelian condition being one phase of the results.

Hybridizing the iceberg white blackberry with the Cuthbert raspberry develops a plant with foliage and growth midway. About half the plants bear fruit which is red like the raspberry, about half bear fruit which is white like the iceberg blackberry; the quality is midway between the blackberry and the raspberry. In the crossed fruit (first generation) the flavor is not superior, but it is quite intermediate between blackberry and raspberry. The form of the receptacle is intermediate. Some of the fruitlets separate at the base, but not above.

In crossing it makes no difference which sex is taken as the male parent; it all depends upon the hereditary tendencies of the sex.

Crosses of wild species yield results similar to those from cultivated species, but the latter are more available. The white blackberry is a wild variation crossed with the Lawton for size and vigor; the result is a

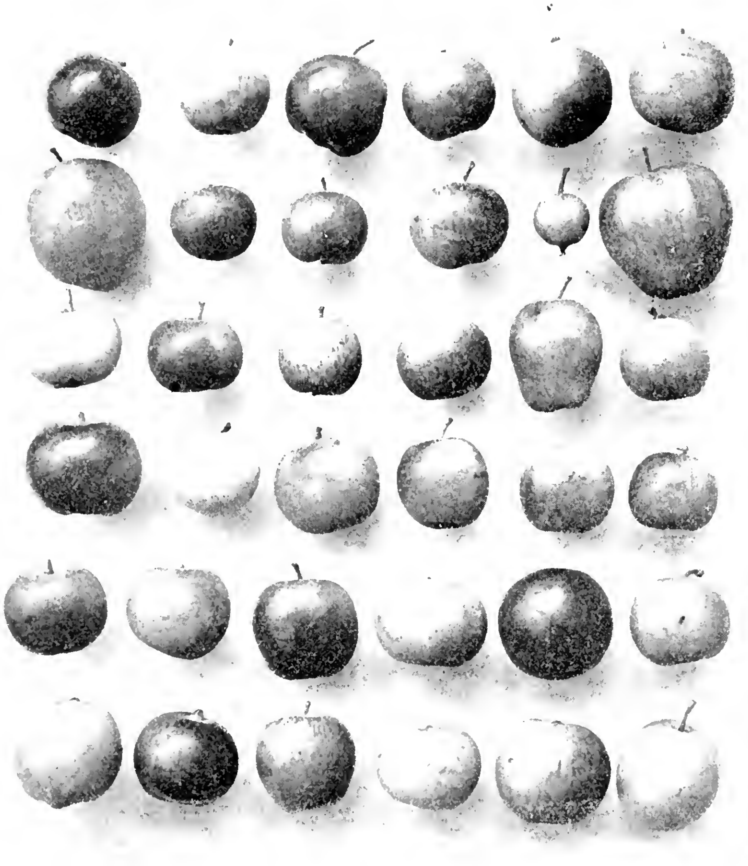
LEAVES OF A BLACKBERRY HYBRID, ALL GROWN FROM SEED OF ONE PLANT.

much clearer white than the wild one, larger, and very much more productive, in these respects fully equal to its staminate parent, the Lawton.

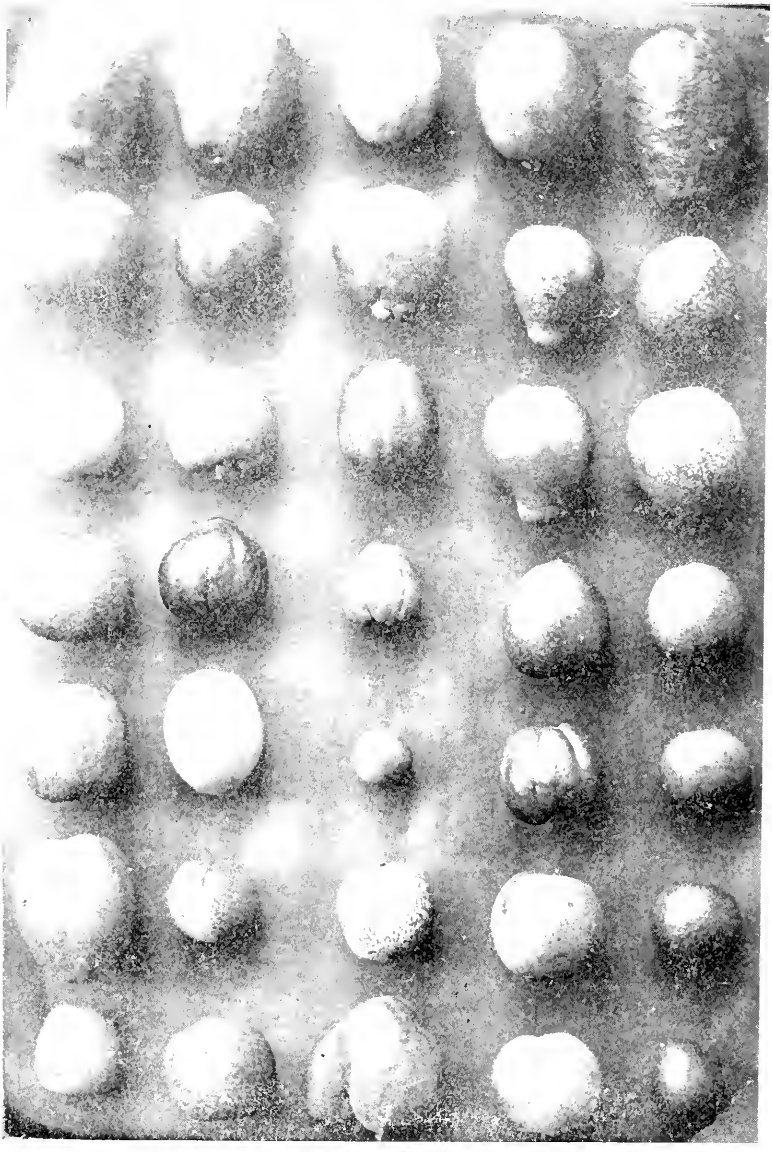
Apples brought up from the south temperate zone are entirely confused here, yielding leaves, buds, flowers and small apples at various seasons. One of these apples in time, however, became adapted to the conditions and developed into one of the best apples in Mendocino County.

"Animals or plants changed by transference from one country to another never quite go back to the old conditions, even if placed in them again, as hereditary tendencies acquired under the new environments, even though latent for many generations may be called forth again under favoring conditions. Exceptions seem to be as important as the rules in this work. Nature leaves so many loopholes that there is almost no rule without exceptions. She does not tie herself up to any unvarying conditions. Adaptability is more important than perseverance."

A blackberry plant with an immense mass of fruit developed from a seedling from the Himalayas. One plant covers 150 square feet, is 8 feet high, and has a bushel or more of fruit. This is only a young, small plant; when full grown this variety is many times larger.



APPLES—ALL SEEDLINGS FROM ONE VARIETY, 'THE EARLY WILLIAMS,' SHOWING ABOUT THE NORMAL VARIATION OF APPLE SEEDLINGS.



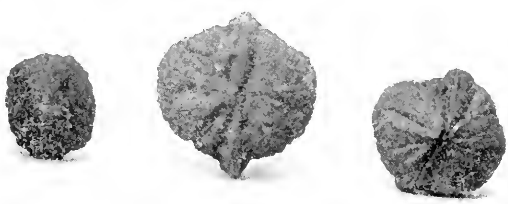
SEEDLINGS OF JAPANESE QUINCES, SHOWING NORMAL VARIATIONS.

A purple larkspur reared by Mr. Burbank is produced by crossing a native blue with a native scarlet, the color being entirely a blend. The blackberry was crossed with apples and with all the various rosaceous plants. Over five thousand plants were produced. The apple-blackberry cross came out essentially apples in foliage and growth, though raised from blackberry seeds. Only two of them ever bloomed, all were thorn-

less, one of them bearing rose-colored flowers. From the mountain ash and blackberry a salmon-colored fruit with no thorns and no albumen in the seed was developed. A hybrid between the English and the black walnut grows fully four times as fast as the English walnut: it bears little fruit. The seedlings from the fruit produce some English, some black, and some hybrid walnuts, and not rarely entirely new forms. Crossing often brings about great vegetative life at the expense of reproductive life, or the reverse. The young (second generation) hybrids of the black walnut and the English walnut show very great variation in their leaves, resembling neither parent. The hybrids of the English and California black walnuts are most rapidly growing trees and unusually productive. The first hybrid, of the English with the Japanese walnut, *Juglans sieboldi*, is largely like the Japanese in the nuts, but rather more like the English in foliage, the second generation being very variable as usual.

THE ORIGINAL AND IMPROVED (SHASTA) DAISY.

By crossing types already crossed, we may often bring out the original stock which had been lost in cultivation. The English walnut has usually five leaflets, the black walnut fifteen to nineteen. The first



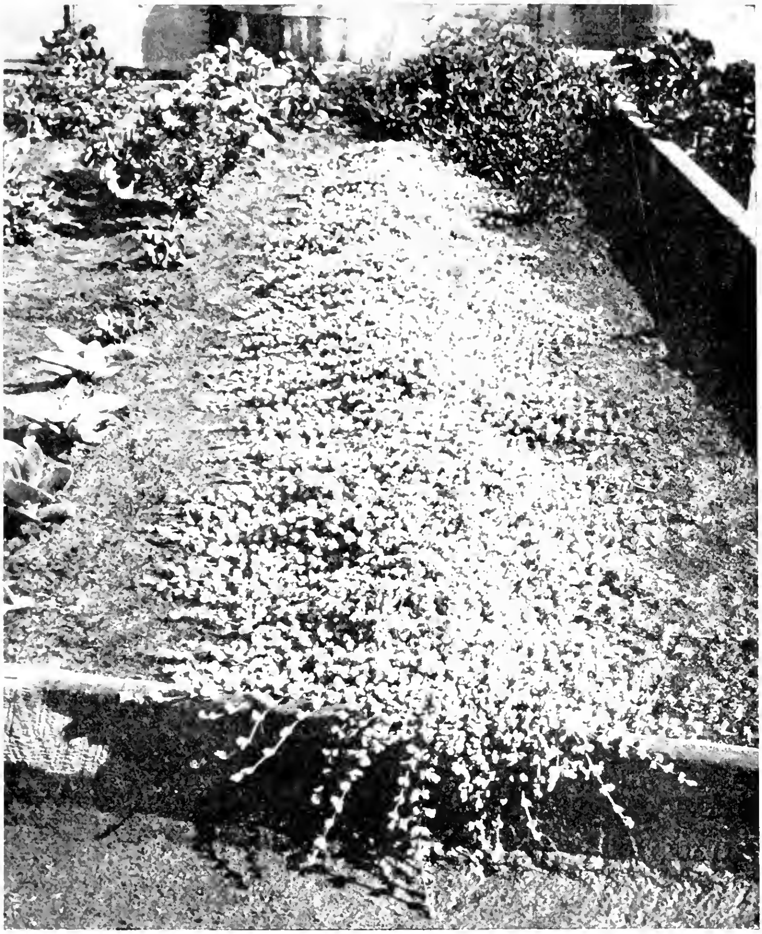
JAPAN WALNUT. RESULT OF CROSS OF THE TWO. ENGLISH WALNUT.

generation hybrid has eleven, with a fragrance to the leaves that no original walnut has. This tendency or trait is just as real as any other. The American walnut (*Juglans nigra*) and the California black walnut (*J. californica*) are closely related species and when hybridized yield fruit of very large size and in enormous quantities.

Descendants of hybrids usually revert to either one or the other parent or break up in all directions. A cross of the eastern black walnut (*Juglans nigra*) with the California nut (*J. californica*) yields a hybrid which is a very great grower. From the seed of this tree a surprising variety of mutations are developed, not only resembling

LEAVES FROM SECOND GENERATION SEEDLINGS FROM CROSS OF COMMON PERSIAN WALNUT (*Juglans regia*) AND CALIFORNIA NATIVE WALNUT.

every possible combination of both parents but numerous strange forms. In fact, among about two thousand seedlings now alive, almost every type or form of walnut foliage may be found. There are startling variations in size, form and number of leaflets, in the size of the plant, in the serration of the margins, in the degree of roughness of the surface, in every feature in which one walnut may differ from another.



HYBRID MESEMBRAYNTHEMUM.

Some time since, a hybrid mesembryanthemum was developed, and lasted for four years, forming an attractive plant with a profusion of white flowers. Then all individuals, whereever located, died at once, doubtless because conditions were adverse; but there was no visible cause of soil, of insect pest, of fungus or of climate. These plants all died from the root up. A hybrid of petunia and nicotiana has abundance of flowers and a large vigorous leaves, but the roots are inadequate. A hybrid red poppy is formed by uniting the opium poppy with the oriental poppy. These hybrids bloom every day of the year, while the blooming season of either parent is only a few weeks, but they yield no seed. The seed capsules are developed in great variety, some of them four to six times as large as the capsules of either parent.

Others are scarcely thicker than the stem which bears them, while others are absolutely and completely absent. This hybrid poppy is tall and generally branches like the opium poppy. It is perennial, although its pistillate or seed ancestor is a short-lived annual. This red poppy can even be divided at the root and multiplied like the perennial oriental poppy. These hybrids have generally a dark mark at the base of the scarlet petals as in the oriental poppy; in some the leaves are smoothish and glaucous, as in the opium poppy; in most, deep green and hairy, more as in the other. Many flowers have their stems coalescent with that of the neighboring flower.

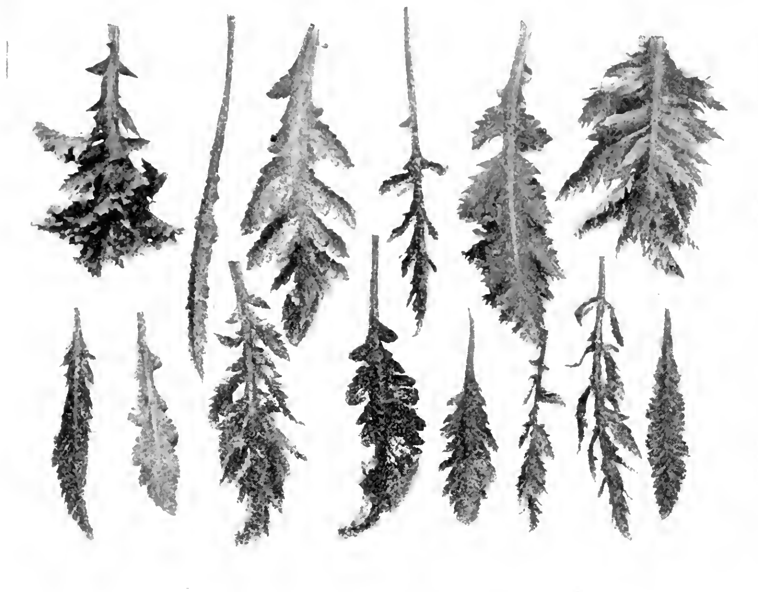
SAMPLE OF HYBRID POPPIES.

"These second generation hybrid poppy plants unexpectedly all proved to be *perennials,* and are now making a tremendous growth; the clusters of foliage of some of them are fourteen to eighteen inches across already. Among this *second* generation hybrid lot of poppies each single plant seems to be different from every other plant in the lot and strange to say the leaves now resemble not only poppy leaves, but celandine, various thistles, primroses, turnips, mustards and numerous other plants are very closely imitated, showing most astounding variations."

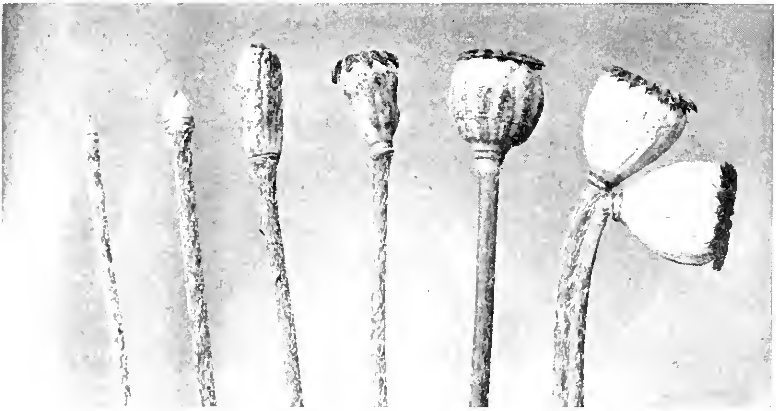
SAMPLE LEAVES OF TWO SPECIES OF BOCCONIA, SHOWING ONE OF THOUSANDS OF CASES OF GREAT VARIATION IN FOLIAGE IN CLOSELY RELATED SPECIES.

The striped amaryllis, *vittata,* hybridized with a Mexican species, *formosissima,* has narrow twisted petals of a very deep scarlet and nearly plain. The leaves are much narrower than in the *vittata,* the stalks more slender, and the plants more profuse bloomers.

Hybridizing crinum with amaryllis develops a plant with a fine



Leaves from Hybrid Poppies, showing unusual variations in foliage even for second generation hybrids. Blossoms vary about as much as the leaves—the habits of the plants also. These are an average random selection from about two thousand second generation seedlings.



Capsules of Second Generation Hybrid Poppies, showing series of variations from complete absence of capsules to capsules of unusual size and to double capsules of unusual size. These selected at random from about 2,000 plants. The individual plants which produce these types generally follow them in all the capsules.

flower but no seeds. Crossing the small hardy white calla with a yellow one which is not hardy, develops, with selection, a hardy yellow calla.

A crinum from Florida is hardy but not handsome. Crossing this with a handsome crinum from Mexico, the plants were selected for those which should be both hardy and handsome. The desired qualities of the two species have been combined and other valuable new qualities incidentally developed as regeneration and selection proceeded.

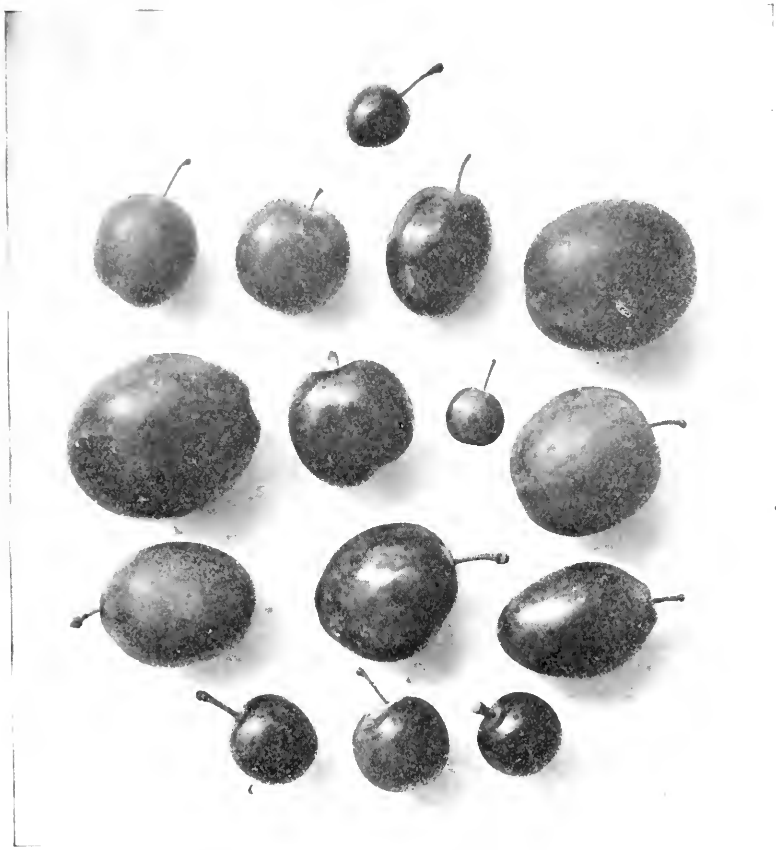
In hybridizing callas, the yellow ones with the white, to form a hardy yellow race, some of the resultant plants have pale flowers, some light yellow, and those chosen are made deep yellow by selection from second and later generations. Both parent plants in this case have leaves blotched with white, and this is found in all the descendants.

Hybridizing the wild flower, *Erysimum arkansanum*, which is yellow, with a native wild white species, resulted in the first generation a perfect blend of yellow and white; with a second generation the species separate completely, about five per cent. of those examined being yellow, the other ninety-five per cent. white; white dominant. With a hybrid *Thalictrum*, seed pods are developed more abundantly than with either parent, but the seeds are not viable.

We may expect variations in form, size, color, quality, fragrance, vigor or any other characteristic. To get variation in any one direction is to open the door to anything else. Hybridizing the Japanese quince with the common quince, we have large-leaved seedlings which look quite different from the parent (common quince). The final result is a seedling looking like the Japanese quince, without the power of continued growth (too wide a cross to blend permanently or profitably).

Some of the black raspberries when hybridized with some of the blackberries usually die when the time comes to bear fruit. Many hybrids perish under the stress of reproduction. The *Amaryllis vittata* is now eight to eleven inches across, being nearly four times as broad as before the work of selection for size was begun, and with vigor and freedom of growth and bloom amazingly increased. On a strip of poor land it grows very small, with narrow leaves and slender flowers, but on the same poor land some of the hybrid variants grow very large and pay no attention to the soil. A variant of *Ampelopsis quinquefolia* has very large leaves, highly colored in the fall, but no fruit. *Mimulus tigrinus* of Europe has very many variations. Its flowers are yellow, with patches of orange and other colors. When crossed with some of our native species, the seedlings are greatly improved in all respects, even in blooming, yet rarely produce seeds.

It is generally much easier to develop variations in seedlings from variegated flowers than from those of solid color (the variegation shows a lack of complete amalgamation). A double mimulus is formed of the *hose-en-hose* sort. One hybrid poppy produces an abortive flower

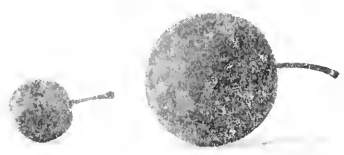


ORIGINAL WILD STONELESS PLUM AT THE TOP AND 14 OF ITS SEEDLINGS WHEN CROSSED WITH THE FRENCH PRUNE BELOW, ABOUT ½ SIZE.

inside the capsule. All seedlings always vary more or less. With the same parent, one fruit may be two and one half or more times the diameter of the other, of a different color, flavor or differing in almost all respects. "There is no prepotency of male or female as such. Prepotency depends wholly on heredity. We can not rely on the stoneless types being prepotent, but a certain number of trees producing stoneless fruit usually come from crossing them with those having stones. The prepotency to produce a stone, or a half stone, having been more thoroughly fixed by ages of stone-producing trees, will perhaps be about ninety-nine times out of one hundred. But other things being equal, there is absolutely no balance in favor of either sex. This may be set down as fixed."

With plum-almond crosses there is every kind of variation in the flowers. Some have all stamens, some have many petals or none, some never open, and some have pistils only.

The Climax plum is a cross of the bitter, flat, tomato-shaped Chinese plum, *Prunus simoni,* and the Japanese plum, *Prunus triflora.* The Chinese plum produces almost no pollen; hardly a grain of it is known, not more than one could put in his eye without feeling it; but the whole fruit shipping industry of the world has been changed by this hybrid plum (Climax) produced by it. With many crosses of many things it is certain that forms of great importance will come out every year, though never in profusion.



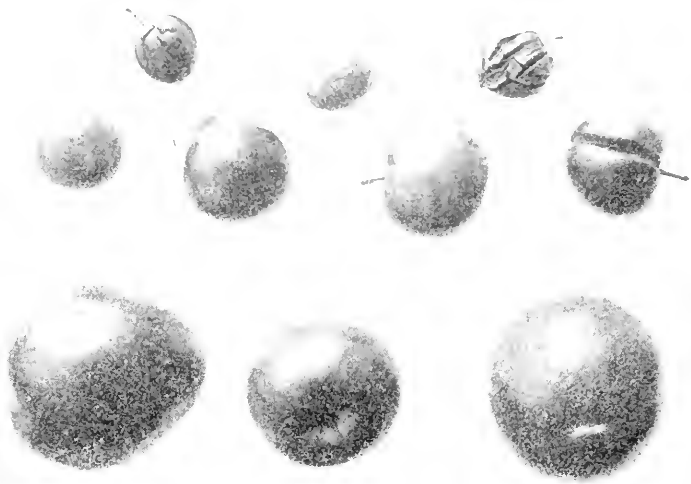
ORIGINAL AND IMPROVED BEACH PLUM.

In developing a spineless cactus for stock-feeding, selections were made from the three hardy northern species, *Opuntia rafinesquii, O, mesacantha* and *O. vulgaris;* these were crossed with *O. tuna. O. ficusindica* and with a small opuntia from Central America, almost thornless.

The cactus has smooth cotyledons, but the first bud is covered with thorns. These thorns have also been eliminated by selecting the smoothest individual seedlings without crossing. Crossing in this case generally interrupts the process, as it brings out well-fixed ancestral traits, but later, to combine the best qualities of several species, crossing and selection must be resorted to. Examples seen were shoots of the original stock, prickly; the second generation, slightly prickly; the third, without thorns; and later the spicules even within the substance of the cactus have been removed so as to make the cactus very excellent food for cattle. This will have very great value in the arid regions. Some cacti lose the thorns on the plant but retain them on the fruit; others *vice versa.* By crossing and extensive and intensive selection a cactus may be improved in various ways besides being deprived of thorns and of the internal spicules in six or less generations; these, by means of cuttings, may be multiplied rapidly to any extent, but the process, to be complete, generally takes longer. This thornless cactus should prove of very great value in the development of desert regions as Arizona or Sonora, as the quantity of food produced per acre is enormous.

The Bartlett plum has the flavor of a Bartlett pear, but even more strongly developed. The 'rice seed' plum has extremely small seeds. The stoneless plum is a cross of the French prune with a wild plum having the stone almost eliminated by a fortuitous variation. The result thus far is a great number of stoneless plums of good size, but in flavor inferior to the best cultivated ones. These are being crossed again to improve the flavor, and new selections made.

Crossing the Japan and the New England chestnut (*Castanea*



TEN VARIETIES OF PLUMS GROWN FROM THE SEED OF THE BURBANK PLUM CROSSED WITH THE APRICOT PLUM, SHOWING VARIATIONS.

japonica and *C. americana*), the trees, leaves, growth and nuts are midway; second generation and later generations as usual show more varied combinations and variations. To breed the burrs off from chestnuts is dangerous, because it allows the birds to get in at the nuts. The

BED OF SEEDLINGS FROM SPINELESS CACTUS, SHOWING HERE AND THERE REVERSION TO THE ORIGINAL SPINE FORM.

burr is originally intended to keep off the birds. In developing a superior variety of the Persian (often called English) walnut (*Juglans regia*), the shell was made too thin, so that the birds could break in. It was necessary to make new selections and crossings to thicken the shell and still retain its other superior qualities.

THALLUS AND FRUIT OF SPINELESS CACTUS.

The Pierce grape was a bud sport from the Isabella, producing much larger fruit. This bud sport remains constant. All the seedlings even from it are similar to the Pierce grape, following the bud sport (*Pierce*) and not reverting to the real parent form of the Isabella. Some ripen early, some late; some are pale, and some are black; but all resemble the Pierce more than the Isabella. Cultivating a choke cherry, the seeds all from one parent tree, many variations are found, although the soil in which they are placed is uniform. Among them was found one variant less bitter than usual; others earlier or later ripening and with larger or smaller fruit or leaves, and an almost bewildering number and variety of other variations. A peach-almond cross often develops a tree as large as ten peach trees or almond trees of the same age. Sometimes a similar cross with different individuals of the same species will produce opposite or totally different results, owing to past heredity, either recent or far back. Crosses are sometimes more vigorous than either parent and more than any descendant, but other cases are just the reverse. The more variant crosses are often less vigorous, and sometimes yield seedlings that can not exist. Sometimes all die in the fruiting season. A peach named 'Quality' is one of the best peaches extant—a cross of the Muir and the Crawford. A cross of the nectrine and peach also produces variant types of value. In some hybrids of petunia and tobacco, the roots fail while the tops may be of unusual vigor. These individuals can only be kept alive for any length of time by grafting, another instance—if other were needed—of the parallelism of crossing and grafting.

THE PLUMCOT—AN ABSOLUTELY NEW FRUIT.

"A character may be latent through many generations or centuries.

appearing when the right cross brings it out; or it may appear under specially favorable or peculiar conditions of growth."

According to Burbank, "the facts of plant life demand a kinetic theory of evolution, a slight change from Huxley's statement that 'matter is a magazine of force,' to that of matter being force alone. The time will come when the theory of ions will be thrown aside and no line left between force and matter. We can not get the right perspective in science unless we go beyond our senses. A dead material universe moved by outside forces is in itself highly improbable, but a universe of force alone is probable, but requires great effort to make it conceivable, because we must conceive it in the terms of our sense experience."

THE PRESENT PROBLEMS OF PALEONTOLOGY.*

BY HENRY FAIRFIELD OSBORN,

DA COSTA PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY. CURATOR OF VERTEBRATE PALEONTOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY. GEOLOGIST AND PALEONTOLOGIST, UNITED STATES GEOLOGICAL SURVEY.

I CONGRATULATE myself that it has fallen to my lot to set forth some of the chief contemporary problems of paleontology, as well as to make an exposition of the prevailing methods of thought in this branch of biology. At the same time I regret that I can cover only one-half of the field, namely, that of the paleontology of the vertebrates. From lack of time and of the special knowledge required to do a great subject justice I am compelled to omit the science of invertebrate fossils and the important biological inductions made by the many able workers in this field. There is positively much in common between the inductions derived from vertebrate and invertebrate evolution and I believe a great service would be rendered to biology by a philosophical comparison and contrast of the methods and results of vertebrate and invertebrate paleontology.

The science of vertebrate fossils is in an extremely healthy state at present. The devotees of the science were never more numerous, never more inspired and certainly never so united in aim as at present. We have suffered some heavy personal losses, not only among the chiefs, but among the younger leaders of the science in recent years; Cope, Marsh, Zittel, Kowalevsky, Baur and Hatcher have gone, but they live in their works and their influence, which vary with the peculiar or characteristic genius of each.

As in every other branch of science, problems multiply like the heads of hydra; no sooner is one laid low than a number of new ones appear; yet we stand on the shoulders of preceding generations, so that if our philosophical vision be correct we gain a wider horizon, while the horizon itself is constantly expanding by discovery.

In discovery the chief theater of interest shifts from continent to continent in an unexpected and almost sensational manner. In 1870, all eyes were centered on North America and especially on Rocky Mountain exploration; for many ensuing years, new and even unthought of orders of beings came to the surface of knowledge, revolutionizing our thought, firmly establishing the evolution theory and

* Address delivered before the Section of Zoology of the International Congress of Arts and Science, September 22, 1904.

appearing to solve some of the most important problems of descent. Then the stage shifted to South America, where an equally surprising revelation of unthought of life was made. We were in the very midst of the more thorough examination of this Patagonian and Pampæan world when the scene of new discovery suddenly changed to North Africa—previously the 'dark continent' of paleontology—and again a complete series of surprises was forthcoming. Each continent has solved its quota of problems and has aroused its quota of new ones. Now we look to central and South Africa, to the practically unknown eastern Asia, and possibly to a portion of the half sunken continent of Antarctica for a future stock of answers and new queries.

Rapid exploration and discovery, however, are not the only symptoms of health in a science; we do not aim to pass down to history as great collectors; we must accumulate conceptions and ideas as rapidly as we accumulate materials; it will be a reproach to our generation if we do not advance as far beyond the intellectual status of Cuvier, Owen, Huxley and Cope as we advance beyond their material status in the way of collections of fossils. We must thoroughly understand where we are in the science, how we are doing our thinking, what we are aiming to accomplish; we must grasp, as the political leader, Tilden, observed, the most important things and do them first.

Paleontology a Branch of Biology.

Let us first cut away any remaining brushwood of misconception as to the position of paleontology among the sciences. I do not wish to quarrel with my superior officers, but I must first record a protest against the fact that in the classification scheme of this congress, in the year of our Lord 1904, paleontology is bracketed as a division of geology. It is chiefly an accident of birth which has connected paleontology with geology; because fossils were first found in the rocks, geology the foster mother was mistaken for the true mother, zoology—a confusion in the birth records which Huxley did his best to correct. The preservation of extinct animals and plants in the rocks is one of the fortunate accidents of time, but to mistake this position as indicative of scientific affinity is about as logical as it would be to bracket the Protozoa, which are principally aquatic organisms, under hydrology, or the Insecta, because of their aerial life, under meteorology. No, this is emphatically a misconception which is still working harm in some museums and institutions of learning. Paleontology is not geology, it is zoology; it succeeds only in so far as it is pursued in the zoological and biological spirit.

In order to make clear the special rôle of paleontology among the biological sciences and at the same time the grateful services which it is enabled to render to its foster science, geology, as well as to geog-

raphy, when pursued in a purely biological spirit, let us employ an imaginary problem. Figure to yourselves a continent absolutely unknown in any of its physical features of earth, climate or configuration; let us imagine that from such an unknown continent all the animals and all the plants could be brought into a vast museum, the only condition being that the latitude and longitude of each specimen should be precisely recorded, and let us further imagine a vast number of investigators of the most thorough zoological and botanical training and with a due share of scientific imagination, set to work on this collection. Such an army of investigators would soon begin to restore the geography of this unknown continent, its fresh, brackish and salt-water confines, its seas, rivers and lakes, its snow peaks, its glaciers, its forests, uplands, plains, meadows and swamps; also even the cosmic relations of this unknown continent, the amount and duration of sunshine as well as something of the chemical constitution of the atmosphere and of the rivers and seas. Such a restoration or series of restorations would be possible only because of the wonderful fitness or adaptation of plants and animals to their environment, for it is not too much to say that they mirror their environment.

At the historic period commemorated by this great exposition of St. Louis when Napoleon concluded to sell half a continent to strengthen his armies, it is true that such a solution of a physical problem by biological analysis might have been conceived by the pupils of Buffon, by Napoleon's great contemporaries Cuvier, Lamarck or St. Hilaire, but the solution itself would not have been possible. It has been rendered possible only by the wonderful advance in the understanding of the adaptation of the living to the lifeless forces of the planet. Finally, it is obvious in such a projection of the physical from the purely biological that the degree of accuracy reached will represent the present state of the science and the extent of its approach toward the final goal of being an exact or complete science. The illustrative figure need not be changed when the words paleozoology and paleobotany are substituted for zoology and botany. We still read with equal clearness the physical or environmental changes of past times in the biological mirror, a mirror often unburnished and incomplete, owing to the interruptions in the paleontological records, but constantly becoming more polished as our knowledge of life and its all pervading relations to the non-life becomes more extensive and more profound.

Such an achievement as the reconstruction of a continent would be impossible in paleontology pursued as geology or as a logical subdivision of geology. The importance of the services which paleontology may render geology as time-keeper of the rocks, or which geology may render paleontology, are so familiar that we need not stop to enumerate them. To emphasize the relation I have elsewhere suggested the phrase, *Non*

paleontologia sine geologia. With other physical sciences paleontology is hardly less intimate; from the physicist it demands time for the evolution of successive waves of organisms, from the geographer it demands continental connections or even whole continents for the passage of land animals and plants. As with geology, what it receives it is ever ready to return in gifts; the new branch of geography, for example, entitled paleogeography, appeals quite as often to the paleontologist as to the geologist for its data.

Problem of the Origin of Fitness.

Naturally the central thought of paleontology as biology is the origin of fitness as the property which above all others distinguishes the living from the non-living. Here the paleontologist enjoys the peculiar advantage of being present at the birth of new characters and watching the course of their development; and to this advantage is attached the peculiar responsibility of observing the birth and course of development of such characters with the utmost accuracy and a mind free from prejudices in favor of any particular hypothesis, with full acquaintance with the phenomena of evolution as they present themselves to the zoologist, the botanist and the experimentalist, and with the philosophical temper which will put every hypothesis to the test of every fact. The laughing remark of Cope on seeing a newly discovered specimen which controverted one of his hypotheses, 'if no one were watching I should be glad to throw that fossil out of the window,' has a serious reality in our often unconscious protection of our own opinions.

The birth of new characters is the crucial point in the origin of fitness. With Darwin himself, with Cope, with Bateson, we do not regard the Darwinian law of selection as the creative or birth factor; by its very terms it operates after there is something of value to select. Forgetting this distinction, some naturalists are so blind as to fail to see that selection is still the supreme factor in evolution in the sense that it produces the most grand and sweeping results as well as the most inconspicuous results in the organic world. Certain of the creative factors can not be seen at all by paleontologists; others, in my opinion, can not be seen by zoologists.

Before looking further into the creation of fitness, let us clear away another misconception, which happens to be of paleontological origin, although paleontologists are not responsible for it. It concerns the history of one of the great theories of the day. Many years ago, Waagen, a German paleontologist, observed that the varieties or minor changes in time (chronological varieties) differ from varieties in space (geographical varieties); that the latter have a variable value and are of small systematic importance, while the former are very constant and,

though seen only in minute features, may always be recognized again. These varieties in time Waagen termed *mutations*. In 1891 Scott unearthed this distinction of Waagen's and clearly defined it as the hereditary or phylogenetic change of animals in time. Previous to this Osborn, without knowing of Waagen's statement, had discussed the same facts of the birth of new characters, describing them as 'definite variations.' Cope, it happens, did not follow this line of thought at all; but many other paleontologists did, notably Hyatt, whose peculiar style and multiplicity of terms obscured his depth of thought and extent of observation. Thus the term *mutation* acquired a definite significance among paleontologists.

It happened that De Vries, the eminent Dutch botanist, reading Scott's paper, mistakenly identified these new characters succeeding each other in time with those which he was observing as occurring contemporaneously in plants, and he adopted Waagen's term for the 'mutation theory,' which he has so brilliantly set forth, of the sudden production of new and stable varieties, from which nature proceeds to select those which are fit.

If paleontologists are correct in their observation, mutations may be figured graphically as an inclined plane, whereas De Vries's phenomena in plants represent a series of steps more or less extensive. Scott expressly excluded the element of discontinuity; and I believe there is no ground whatever for the assertion that the phenomena first named mutations by Waagen and independently observed by many paleontologists, are identical with the phenomena observed by De Vries in plants.

On the contrary, De Vries's facts accord with the favorite hypothesis of St. Hilaire. They demonstrate the law of *saltation*. This is the inevitable interpretation of the expositions of De Vries himself, of Hubrecht, and of the more recent references of Bateson in his British Association address. That saltation is a constant phenomenon in nature, a *vera causa* of evolution, no one can longer deny. Bateson shows that it harmonizes with Mendel's conceptions of heredity, and it may be regarded as *par excellence* the contribution of the experimental method.

Similarly, I regard mutation as a quite distinct phenomenon, and as *par excellence* the contribution of the paleontological method; it is the gradual rise of new adaptive characters neither by the selection of accidental variations nor by saltation, but by origin in an obscure and almost invisible form, followed by direct increase and development in successive generations until a stage of actual usefulness is reached, where perhaps selection may begin to operate. While clearly setting forth the difficulties, I at one time attributed definite variation or mutation to Lamarck's principle of the inherited effects of habit as the

only assignable cause; subsequently I realized that it was not explainable by the Lamarckian hypothesis.

I then attributed it to an unknown law of evolution, and there I believe it rests to-day, namely: as a process of which we do not know the cause. Still more recently, however, comes the discovery that original kinship is partly at least a control-principle. For example, in the descent of independent stocks of hornless animals arising from a common stock, rudimentary horn cores are found to appear independently in exactly the same region of the skull, indicating a kind of predetermination in the stock, or potential of similar evolution. The facts on which this law of mutation, properly called, rests have been misunderstood, totally denied, or explained away by selectionists as survivals of favorable out of indiscriminate variations. Even my colleague, Scott, has identified these phenomena with the saltations of De Vries. Nevertheless, I regard the genesis of new adaptive characters from almost imperceptible beginnings as a *vera causa,* and as one of the greatest problems we have to solve.

That a natural solution will be found goes without saying, although this principle, as stated, is undoubtedly of a teleological nature. Its philosophical bearings are of far reaching importance. Just as we demand a continent to transfer land animals from Australia to South America, so we demand a natural law to explain these facts.

The creative factors of fitness cooperating with selection, which, in my judgment, are now well demonstrated, reside either primarily in the environment, in the bodies of animals, or in the germinal cells—they all ultimately find their way into the germinal cells. They may be summarized as follows:

1. *Segregation.*—Besides the familiar geographical segregation of animals, which reaches its highest expression in insular forms, such as the pygmy fossil elephants of Malta and those recently discovered in Cyprus (Wade), there is the no less effective *segregation of habit* among animals existing in the same geographical regions and under the same climatic conditions, but seeking different varieties of food on different kinds of soil. These give rise to what I have called local adaptive radiations, a principle which explains the occurrence in the same country, and almost side by side, of very conservative as well as very progressive forms.

2. *Adaptive Modification.*—This is a plastic principle which tends in the course of life to an increasing fitness of the bodies of individuals to their special environments and habits, well illustrated among men in the influence of various trades and occupations and operating both in active and in passive structures. Consistent with the adaptive modification principle is the fact that every individual requires habit and environment to model it into its parental form; and in every change of environment or habit every individual is carried an infinitesimal

degree beyond the parental form; the wonderful phenomena of correlated development which puzzled Spencer so much are chiefly attributable to this principle.

These adaptive modifications are not directly inherited, as Lamarck supposed, but acting through long periods of time there results the *organic selection* (Morgan, Baldwin, Osborn), of those individuals in which hereditary predisposition happens most closely to coincide with adaptive modification, and there thus finally comes about an apparent, but not real, inheritance of acquired characters, as Lamarck, Spencer and Cope supposed.

3. *Variations of Degree.*—We should by no means exclude as true causes of evolution associated with both the above factors, the selection of those variations of degree or around a mean which conform to Quetelet's curve, the subject of the chief investigations of the Galton school, of Pearson and of Weldon, and which form the strongest remaining ground for Darwin's theory of selection in connection with fortuitous variation. For example, I regard the appearance of long-necked giraffes, of slender-limbed ruminants and horses, of long-snouted aquatic vertebrates, as instances of the selection of variations around a mean rather than of the selection of saltations. The selection of such variations where they happen to be adaptive has been an incessant cause of evolution.

4. *Saltation.*—Although Geoffroy St. Hilaire argued for paleontological evolution by saltation, I do not think we have much evidence in paleontology for the saltation theory. In the nature of the case, we can not expect to recognize such evidence even where it may exist, because wherever a new form appears or a new character arises, as it were, suddenly, we must suspect that this appearance is due to absence of the connecting transitional links to an older form. The whole tendency of paleontological discovery is to resolve what are apparently saltations or discontinuities into processes of continuous change. This, however, by no means precludes saltation from being a *vera causa* in past time, as rising from 'unknown' causes in the germ cells and as forming the materials from which nature may select the saltations which are adaptive from those which are inadaptive. The paleontologist has every reason to believe that he finds saltations in the sudden variations in the number of vertebræ of the neck, of the back, of the sacral region, for example. In the many familiar cases of the abbreviation or elongation of the vertebral column in adaptation to certain habits, a vertebra in the middle of a series can not dwindle out of existence, it must suddenly drop out or suddenly appear.

5. *Mutation.*—These new characters are also germinal in origin, because they appear in the teeth, which are structures fully formed beneath the surface before they pierce the gum, and therefore not subsequently modeled by adaptive modification, as the bones, muscles and

all the other tissues of the body are. Mutations are found arising according to partly known influences of kinship. They do not, so far as we observe, possess adaptive value when they first appear, but then frequently, if not always, develop into a stage of usefulness.

Fitness is, therefore, the central thought of modern paleontology in its most comprehensive sense, as embracing fitness in the very remote past, in its evolution toward the present and in its tendencies for the future. Just as the uniformitarian method of Lyell transformed geology, so the uniformitarian method is penetrating paleontology and making observations of animal and plant life as it is to-day the basis of the understanding of animal and plant life as it was from the beginning. Here again paleontology is not merely an auxiliary to zoology; it is chief of a division and enjoys certain unique advantages. We pass in review with the pedigrees and the prodigies of fitness, the entirely unreasonable, irrational, paradoxical extremes of structure, such, for example, as the pterosaurs, which far surpass in boldness and ingenuity of design any of the creations of the modern yacht builder which are mistakenly regarded by some as having reached an absurd extreme.

Problem of Historical Study.

The paleontologist must also be a historian; he has to deal with lineage, with ancestors, he comes directly upon the problem of kinship or relationship, and he has to determine the various means of distinguishing the true from the apparent relationships. It happens that fitness, while fascinating in itself, has led even the most faithful and skilful into the most devious paths away from the truth. The explanation of this apparent contradiction is in this wise. The ingenuity of nature in adapting animals is astounding, but it is not infinite; the same devices are resorted to repeatedly to accomplish the same purposes. In the evolution of long-snouted rapacious swimming forms, for example, we have already discovered that nature has repeated herself twenty-four times in employing the same processes to accomplish the same ends in entirely different families of animals.

This introduces us to one of the two great ideas which we must employ in the interpretation of facts, namely, the *idea of analogy.* We see far more clearly than Huxley did the force of this idea. Owen, Cope, Scott, Fraas and many others, under the terms 'parallelism,' 'convergence,' 'homoplasy,' have developed the force of the old Aristotelian notion that analogy is a similarity of habit, and that in the course of evolution a similarity of habit finally results in a close or exact similarity of structure; this similarity of structure is mistaken as an evidence of kinship. Analogous evolution does not stop in its far reaching consequences with analogies in organs; it moulds animals as a whole into similar form, as, for example, the ichthyosaurs, sharks

and dolphins; still more it moulds similar and larger groups of animals into similar lines or radii of specialization. Thus we reach the grand idea of analogy as operating in the divergencies or adaptive radiations of groups, according to which great orders of animals tend in their families and suborders to minic other orders, and the faunæ or collective orders of continents to mimic the faunæ of other continents.

Amid this repetition on a grand scale of similar adaptations, which is altogether comparable to what we know as having occurred over and over again in human history, the paleontologist as a historian must keep constantly before him the second great *idea of homogeny,* of real ancestral kinship, of direct blood descent and hereditary relationship. The shark and the ichthyosaur superficially look alike, but their germ cells are radically different, their external resemblances are a mere veneer of adaptation so deceptive, however, that it may be a matter of half a century before we recognize the wolf beneath the clothing of the sheep, or the ass in the lion's skin.

These two great ideas of analogy or similarity of habit, and homogeny or similarity of descent, do not run on the same lines; they are the woof and the warp of animal history. Analogy corresponds to the woof or horizontal strands which tie animals together by their superficial resemblances in the present, homogenies are the warp, or the fundamental vertical strands which connect animals with their ancestors and their successors. The far reaching extent of analogous evolution was only dimly perceived by Huxley, and constituted his one great defect as a philosophical anatomist. Its power of transforming unlike and unrelated animals has accomplished miracles in the way of producing a likeness so exact that the inference of kinship is almost irresistible.

The paleontologist who would succeed as historian must first, therefore, render himself immune to the misguiding influences of analogy by taking certain further precautions which will now be explained by watching his procedure as historian.

Paleontology as the history of life takes its place in the background of recorded history and archeology, and simply from the standpoint of the human pedigree is of transcendent interest. Although it has progressed far beyond the dreams of Darwin and Huxley, the first general statement which must be made is that the actual points of contact between the grand divisions of the animal and plant kingdom, as well as between the lesser and even many of the minor divisions, have yet to be discovered. You recall that the older grand divisions of the Vertebrata, to which we must confine our attention, were suggested by the so-called Ages of Fishes, of Amphibians, of Reptiles and of Mammals. Even within these grand divisions we observe a succession of more or less closely analogous groups. Each of these groups has its

more or less central starting point in a smaller and older group which contains a large number of primitive or generalized characters.

The search for the primitive central form is always made by the same method of reasoning, a method which was first clearly outlined by Huxley, namely, by the more or less ideal reconstruction of the primitive central form from which radiation has occurred. This is a very difficult matter where the primitive central form is not preserved either living or as a fossil. In such instances we may by analysis of all the existing forms prophesy the structure of the primitive central form, as Huxley, Kowalevsky and Cope did in the case of the hoofed animals, a prophecy which was nearly fulfilled by the discovery in northern Wyoming of *Phenacodus*. In other more fortunate cases the primitive central form survives both living and fossil, as in the remarkable instance of *Paleohatteria* of the Permian and the Tuatera lizard (*Hatteria*) of New Zealand, which gave rise to the grand adaptive radiation of the lizards, mosasaurs, dinosaurs, crocodiles, phytosaurs and probably of the ichthyosaurs.

In the reconstruction of these primitive central forms, we must naturally discriminate between analogy and homogeny, and paleontologists are not agreed in all cases on such discrimination. On the border region, in fact, where the primitive central forms are still unknown, where analogy has reached its most perfect climaxes and imitations, are found the great paleontological controversies of to-day. For example, among the paleozoic fishes, the armored ostracoderms (*Pteraspis, Cephalaspis, Pterichthys*) and the arthognaths (*Coccosteus, Dinichthys*) by some authors (Hay, Regan, Jaekel) are placed in the single group of placoderms, while by other authors (Smith Woodward and Dean) they are regarded as entirely independent and superficially analogous groups. The dipnoi or lung fishes (*Ceratodus, Protopterus*) present so many analogies with the Amphibians (salamanders and frogs) that they were long regarded as ancestors of the latter; but more searching anatomical and paleontological analyses and recent embryological discoveries have proved that the dipnoi and amphibia are parallel analogous groups descended alike from the crossopterygian fishes, fishes which are now represented only by the bichir (*Polypterus*) of Africa. It is interesting to recall parenthetically that two naturalists, Harrington, an American, and Budgett, an Englishman, have given their lives to the solution of this problem in searching for the embryology of *Polypterus*. The latter explorer only was successful.

Missing Links between the Great Classes of Vertebrates.

Among the varied fins of the crossopterygians we have nearly, but not actually, discovered the prototype of the hand and the foot, the fingers and toes of the primordial amphibian. Volumes upon volumes

have been written by embryologists and comparative anatomists on the hypothetical transformation of the fin into the hand. Considering the supreme value of the hand and foot in vertebrate history, this was certainly the most momentous transformation of all and worthy of volumes of speculation; but as a matter of fact, the speculation has been a total failure, and this problem of problems will only be settled by the future discovery in Devonian rocks of the actual connecting link, which will be a partly air-breathing fish, capable of emerging upon land, in which the cartilages of the fin will be found disposed very much as in the limbs of the earliest Carboniferous amphibians. The unity of composition in the hand and the foot points to an original similarity of habit in the use of these organs.

This missing point of contact, or of the actual link between amphibians and fishes, is equally characteristic of paleontology as history from the top to the bottom of the animal scale. We are positive that Amphibians descended from fishes, probably of the crossopterygian kind, but the link still eludes us; we have brought the reptiles within close reach of the amphibians, but the direct link is still to be found; mammals are in close proximity to a certain order of reptiles, but the connecting form is still undiscovered; man himself is not far from the various types of anthropoid apes, but his actual connecting relationship is unknown.

We are no longer content, however, with these approaches to actual contact and genetic kinship, we have toiled so long both by discovery and by the elimination of one error after another, and are so near the promised land, we can hardly restrain our impatience. I venture to predict that the contact of the Amphibia with the fishes will be found either in America or Europe. No such prediction could be safely made regarding the connecting form between the amphibians and reptiles, because America, Eurasia and Africa all show in contemporaneous deposits evidence that such connection may be discovered at any time. The transformation from reptiles to birds will probably be found in the Permian of America or Eurasia; chances of connecting the mammals with the reptiles are decidedly brightest in South Africa; while in Europe, or more probably in Asia, we shall connect man with generalized catarhine primates.

Passing from these larger questions of the relations of the great classes of vertebrates to each other, let us review the problems arising in the individual evolution of the classes themselves.

Geographical Problems.

The primordial, solid-skulled or stegocephalian amphibia of the Permian diverged into a great variety of forms which wandered over Eurasia and North America so freely that, for example, we find as close a resemblance between certain Würtemberg and New Mexican genera

(*Metopias*) as between the existing stag of Europe and the wapiti deer. Which branch of these primordial amphibians gave rise to the modern frogs and salamanders we do not know. This and hundreds of similar facts suggest the vital importance of paleogeography.

As regards paleogeography, the great induction can be made that, throughout the whole period of vertebrate evolution and until comparatively recent times, Europe, Asia and North America constituted one continent and one life region, or Arctogæa (Huxley 1868, Blanford 1890), with which the continents of the southern hemisphere, namely, Africa, South America and Australia, were intermittently, but not continuously connected by land. A great southerly continent, Notogæa (Huxley 1868), connected with a south polar Antarctica, now submerged, is a theory very widely supported by zoologists and, I believe, by botanists, although its existence is still denied by certain geographers (Murray). We find Permian, Jurassic, late Cretaceous and early Tertiary proofs of Antarctica in the fresh-water crustaceans (Ortmann), in fresh-water fishes (Gill), in littoral mollusca (Ortmann), in reptiles (Smith Woodward and Osborn), in birds (Forbes and Milne Edwards), in worms (Beddard), in the Australian animals (Spencer), in the fossil mollusca of Patagonia (Ortmann) and in the fossil mammals of Patagonia (Ameghino). To marshal and critically examine all this evidence and convert this most convenient Antarctic hypothesis into an established working theory I consider one of the most pressing problems of the day.

Problem of the Source of the Reptiles and Mammals.

Returning from this geographical détour to paleontology as history, we should first note that already in the Permian there was developed such an astonishing variety and differentiation of the reptiles that we must look to future discoveries in the Carboniferous to find the actual points of descent of reptiles from the amphibia. These Permian and Lower Triassic reptiles are of three kinds, comparable to a parent (Cotylosauria) and two offspring (Anomodontia and Diaptosauria). In the parent group (the Cotylosauria, or solid-skulled reptiles,) we find so many fundamental similarities to the Stegocephalia, or solid-skulled amphibia, that only by the possession of many parts of the body can we surely ditinguish reptile from amphibian remains. The primordial reptile was probably altogether a land animal continuously using its limbs in awkward progression, bringing forth its young by land-laid eggs and probably possessing gills only as vestiges. These cotylosaurs show very wide geographical distribution, South Africa, Siberia, Great Britain and North America, and equally remarkable adaptive radiations of habit into small and large, horned and hornless types, some of which were certainly dying out branches, while others led into the two offspring groups.

Leaving this parental order, in the Permian and Lower Trias, we first see in the older offspring, the Anomodontia, reptiles of varied size and description, carnivorous and herbivorous in habit, most abundantly found in South Africa, in Asia and in Europe, and not at all as yet in America, either North or South. The high degree of fitness for different habits, or radiation, of the Anomodonts is distinguished from that of any other reptiles at any time by its numerous analogies to the radiation of the mammals, namely, into very large and very small forms, into carnivorous and herbivorous, into terrestrial and possibly into aquatic types; in fact, some of these animals, if seen on land to-day might readily be mistaken for mammals.

The second offspring of the Cotylosauria, on the contrary, the Diaptosauria, are essentially and unmistakably saurians; that is, if seen about us to-day they would undoubtedly at first be described as lizards. They were still more broadly cosmopolitan in range, being scattered over both Americas (Pelycosauria, Proganosauria), Europe (Protorosauria, Rhynchosauria), Asia (Rhynchosauria) and Africa (Proganosauria, Rhynchosauria). They are also found highly diversified in type, but all their analogies of fitness are with the reptiles and not with the mammals. It is of prime importance that more of these diaptosaurs be found, and that those already known in the museums should be more critically examined. What we already know, however, enables us to establish the following facts: first, that the parentage of these animals is more probably among the cotylosaurs than among the anomodonts, and second that already in the Permian they had formed a sufficiently large number of branches to be regarded as a fully evolved radiation.

Problem of the Adaptation of the Mesozoic Reptiles.

In the Triassic the offspring of the anomodonts and of the diaptosaurs appear as the third generation from the cotylosaurs.

The recurrent difficulty arises that the actual points of contact or transition from the anomodonts are wanting, and we must continue to reason by the ideal reconstruction of the hypothetical linking forms. Such reasoning connects the Testudinata (turtles and tortoises), the Sauropterygia, or marine plesiosaurs, and, singularly enough, our own ancestors, the primordial mammals, with the group of anomodonts and not at all with that of the diaptosaurs. Here in the Upper Permian and Lower Trias we must await both discovery and the closest critical analysis, but if this still hypothetical affiliation be confirmed by discovery, as I personally am sanguine it will be, then it will be true to say that the mammals, and hence man, are much more nearly affiliated to the anomodonts than to either the lizards or snakes, which are both on the great Diaptosaur branch. Our presence on the great Anomodont branch and remoteness from the creeping and crawling

reptiles will perhaps afford some consolation to those who still shrink from the ultimate consequences of Darwin's 'Descent of Man.' As regards degrees of probability, it must be said that while the affiliation of the Plesiosaurs and Testudinata with the Anomodont group still requires confirmation, the connection of the mammals with certain Anomodonts (Theriodontia) is not only probable but is almost on the verge of actual demonstration, and at present it seems likely that the Karoo Desert of South Africa will enjoy the honor of yielding the final answer to the problem of the *origin of mammals,* which has has stirred comparative anatomists for the last sixty years.

Turning to the progeny of the other branch, the Permian diaptosaurs, we find them embracing (with the exception of the Testudinata and plesiosaurs) not only vast reptilian armies, marshaling into thirteen orders, mastering the distinctive Age of Reptiles (Triassic, Jurassic and Cretaceous), and surviving in the four existing orders of lizards, snakes, crocodiles and tuateras, but we also find them giving off the birds as their most aristocratic descendants. The bold conception of the connection between these thirteen highly diversified orders and a simple ancestral form of diaptosaur, typified by the Permian *Palæohatteria* or the surviving *Hatteria* (tuatera of New Zealand) we owe chiefly to the genius of Baur, a Bavarian by birth, an American by adoption. Absolutely diverse as these modern and extinct orders are, whatever material for analysis we adopt, whether paleontological, anatomical or embryological, the result is always the same—the reconstructed primordial central form is always the little diaptosaurian lizard. The actual lines of connection, however, are still to be traced into the great radiations of the Mesozoic.

The chief impression derived from the survey of this second branch of the Reptiles in the Mesozoic as a whole is again of radiations and subradiations from central forms and the frequent independent evolution of analogous types. The aquatic life had been already chosen by the plesiosaurs and by some of the turtles, as well as by members of three diaptosaur orders (Proganosauria, Choristodera, certain Rhynchocephalia), two of which were surviving in Jurassic times. Yet it is independently again chosen by four distinct Triassic orders, always beginning with a fresh-water phase (Parasuchia, Crocodilia), and sometimes terminating in a high sea phase (Ichthyosauria, Mosasauria, Crocodilia). In the Jurassic period there were altogether no less than six orders of reptiles which had independently abandoned terrestrial life and acquired more or less perfect adaptation to aquatic life. Nature, limited in her resources of outfitting for aquatic life, fashioned so many of these animals into like form, it is small wonder that only within the last two years have we finally distinguished all the similarities of analogous habit from the similarities of real kinship.

The most conservative members of this second branch are the

terrestrial, four-footed, persistently saurian or lizard-like forms, the tuateras and the true lizards; but from these types again there radiated off one of the marine orders (Mosasauria), the limbless snakes (Ophidia), while the lizards themselves have in recent times diverged almost to the point of true ordinal separation.

The most highly specialized members of this second branch are of course the flying pterosaurs, of whose ancestry we know nothing. Also in a grand division by themselves there evolved the dinosaurs, distinctively terrestrial, ambulatory, originally carnivorous, and probably more or less bipedal animals. Not far from the stem of the dinosaurs was also the source of the birds, also distinguished by bipedalism.

The working plan of creation becomes day by day more clear; it is, that each group, given time and space, will not only be fruitful and multiply, but will diversify in the search for every form of food by every possible method. Specialization in the long run proves fatal; the most specialized branches die out; the members of the least specialized branches become the centers or stem forms of new radiations.

The Mammals of Four Continents.

So it is among the mammals, in which these principles find new and beautiful illustrations, although our knowledge of the early phases is fragmentary in the extreme. Our sole light on the first phase, in fact, is that obtained from the two surviving monotremes of the Australian region; from this extremely reptilian and egg-laying monotreme phase it appears, although opinion is divided on this point, that before the Jurassic period (*i. e.*, already in the Trias) two branches were given off, the placental, from which sprang all the modernized mammals and the marsupial.

The marsupials appear to have passed through an arboreal or tree life condition, something similar to that seen in the modern opossum. The marsupials found their opportunity for unchecked adaptive radiation in Australia and despite the disadvantage of starting from a specialized arboreal type (Huxley, Dollo, Bensley), through the later Cretaceous and entire Tertiary a richly diversified fauna evolves, partly imitating the placentals and partly inventing entirely new and very peculiar forms of mammals, such as the kangaroo.

The oldest placental radiation which is fully known is that which was first perceived in Europe and fully recognized by the discovery in 1880 of the basal Eocene mammals of North America—it may be called the Cretaceous radiation. These mammals are distinctly antique, small-brained, clumsily built, diversified, imitative both of the marsupial and of the subsequent placental radiations; and our fuller knowledge of them after twenty-five years of research is at once satisfying and disappointing, satisfying because it gives us prototypes of the higher or modern mammals, disappointing because few if any of

these prototypes connect with the modern mammals. This fauna is found in the Cretaceous and basal Eocene of Europe, North America, and possibly in Patagonian beds of South America (Ameghino), and while giving rise to many dying-out branches, by theory furnished the original spring from which the great radiations of modern mammals flowed. But practically again we await the direct connections and the removal of many difficulties in this theory. In fact, one of the great problems of the present day is to ascertain whether this radiation of Cretaceous mammals actually furnished the stock from which the modern mammals sprang, or whether there was also some other generalized source.

The Tertiary, or Age of Mammals, presents the picture of the dying out of these Cretaceous mammals in competition with the direct ancestors of the modern mammals. I use the word modern advisedly, because even the small horses, tapirs, rhinoceroses, wolves, foxes and other mammals of the early Tertiary are essentially modern in brain development and in the mechanics of the skeleton as compared with the small brained, ill-formed and awkward Cretaceous mammals.

Whatever the origin, two great facts have been established: *first,* the modern mammals suddenly appear in the Lower Eocene (as distinguished from the basal Eocene, in which the Cretaceous mammals are found), and *second,* they enjoy a more or less independent evolution and radiation on each of the four great continents. There thus arose the four peculiar or indigenous continental faunæ of South America, of North America, of Europe and Asia or Eurasia and of Africa. Of these South America was by far the most isolated and unique in its animal life. North America and Eurasia were much the closest, and Africa acquired a half way position between isolation and companionship with Eurasia.

South America.—The most surprising result of recent discovery is that the foreign element mingled with the early indigenous South American fauna is not at all North American but Australian. The wonderful variety of eight orders of indigenous rodents, hoofed animals, edentates and other herbivores were preyed upon by carnivores of the marsupial radiation from Australia, which apparently came overland by way of Antarctica. There are possibly here also some South African foreigners. The South American radiation more or less closely imitated that of the northern hemisphere. Late in Tertiary times North America exchanged its animal products with South America, practically to the elimination of the latter.

Eurasia and North America.—Each of these continents contained four orders of mammals in common with South America, namely, the Primates (monkeys), the Insectivores (moles and shrews), the Rodents (porcupines, mice, etc.), and the Edentates (armadillos, etc.). From some early Tertiary source North America, Eurasia and Africa also acquired in common four great orders of mammals which are not found

at all in the indigenous fauna of South America. These are the Carnivores (dogs, cats, etc.), the Artiodactyls (deer, bovines, camels, and pigs), the Perissodactyla (horses, rhinoceroses and tapirs), and the Cheiroptera (bats). Migration and animal intercommunication between North America and Eurasia was very frequent. The history of these nine orders of mammals in North America and Eurasia developed as follows: Certain families indigenous to North America both evolved and remained here, others finally migrated into Europe and South America. Similarly Eurasia had its continuous evolution into forms which remained at home as well as into those which finally migrated into North America and even into South America.

Africa.—The most astonishing and gratifying features of recent paleontological progress has been the revelation of what was taking place in Africa at the same time (Andrews and Beadnell). This discovery came with its quota of unthought of forms, also with the representative of three orders which it had been prophesied would be found there, namely, the Proboscidea (elephants and mastodons), the Sirenia (manatees and dugongs), and the Hyracoidea (conies). The basis of this prophecy was the anomalous fact that these animals suddenly appeared in Europe in the Miocene and Pliocene fully formed and without any ancestral bearings; it was certain that they had evolved somewhere, and Africa seemed the most probable home, rather than the currently accepted unknown regions of Asia. Thus by a sudden bound paleontology gains the early Tertiary pedigree of the elephants and of two if not three other orders.

Africa in the early Tertiary, whether from the absence of land connections or from climatic barriers, was a very independent zoological region. Some predatory Cretaceous mammals (Creodonta or primitive Carnivores) found their way in there, also certain peculiar artiodactyls (Hyopotamids). Here also were two remarkable types of mammals (*Arsinoitherium, Barytherium*) which have no known affinities elsewhere, as well as the extremely aberrant Cetaceans or Zeuglodonts.

The Outlook.

From all these continents we have, therefore, finally gathered the main history during the Tertiary period of eighteen orders of mammals. We have still to solve the origin of the cetaceans or whales, still to connect many of these orders which we call 'modern' with their sources in the basal Eocene and Upper Cretaceous, still to follow the routes of travel which they took from continent to continent. Encouraged by the prodigious progress of the past twenty-five years, we are confident that twenty-five years more will see all the present problems of history solved, and judging by past experience we may look for the addition of as many new and no less important ones.

SOCIAL AND POLITICAL EFFECTS OF IMMIGRATION.

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THE assimilation of hundreds of thousands of aliens every year undoubtedly produces social and political effects worthy of close study, which are overlooked by some and exaggerated by others.

The subject of the illiteracy of immigrants brings us naturally to the question of illiteracy at home, and statistics show many remarkable things in this connection. The illiteracy of the United States as a whole is something over eleven per cent., while the percentage of illiteracy among immigrants from England, Ireland, Scotland, Wales, Norway, Sweden, Denmark, Finland, France or Germany is 4 per cent. or less.

Another fact demonstrated by statistics is that in the states which receive a great proportion of aliens every year, the percentage of illiteracy is low, while in the states where the percentage of foreigners is lowest, as in Georgia, Tennessee and Kentucky, the percentage of illiteracy for the state is very high.

The question of illiteracy in our own country is largely a question of presence or absence of schools, and statistics show that the immigrants go to the states which have the best common school system and are thus best fitted to reduce their illiteracy. The fact that illiteracy in New York, Pennsylvania, Illinois and Massachusetts has decreased in spite of the thousands of aliens received every year, speaks well not only for the public school system of these states, but also for the adaptability of the immigrant and his desire for education.

Thus it will be seen from the tables given below that, although illiteracy is high among the foreign born in cities as compared with native whites, the native white children of foreign born parents compare favorably with children of the native white. In regard to percentage of illiteracy and school attendance, Table I. shows that the illiteracy of the foreign born is reduced in one generation, as shown by the native children of foreign parents, from 12.9 per cent. to 1.6 per cent. It also shows that the native children of foreign parents have a much lower percentage of illiteracy than the native whites of native parentage.

Table II. shows that a greater percentage of native white children of foreign parentage attend school between the ages of five and fourteen, than of native whites of native parentage. Table III. shows that

native whites of foreign parentage attend more steadily and persistently than native whites of native parentage, and in this regard the foreign born children lead both the other classes.

Table I.

Nativity and Parentage.	Percentage of Illiteracy.	
	1890.	1900.
Native white of foreign parents	2.2	1.6
Native white of native parents	6.2	5.7
Foreign white	13.1	12.9
Total white	7.7	6.2

Table II.

Nativity.	Age.	
	5 to 9 Years.	10 to 14 Years.
Native white of foreign parents	59.1 per cent.	86.2 per cent.
Native white of native parents	48.6 " "	83.8 " "
Foreign white	58.2 " "	73.0 " "

Table III.

Nativity and Parentage.	Percentage of School Children Attending School Six Months or More in Each Year.	
	Males.	Females.
Native white of foreign parents	88.7	90.6
Native white of native parents	68.7	71.4
Foreign white	89.1	90.8

Illiteracy is seldom a matter of choice with the peasant. It is usually a matter of bad government. The governments of certain countries maintain no free school system, and paid schools of academies are out of the reach of the miserable peasants.

In other countries the government places monetary or religious restrictions upon certain races which prevent their attendance at school. One often hears the query, 'What is the effect of a mass of illiterate foreigners upon society?' There is very little effect. The illiterate foreigners in our own large cities are ostracized socially, as strictly as the negro in the south. 'These foreigners do not assimilate' is heard every day. How can they? They can not take the initiative. The Italian, or the Jew, or the Slav, do not shrink away from their American neighbors more than their American neighbors shrink from them.

This mutual aloofness will persist through one or two generations. No sane man expects the Americanization of any but English-speaking immigrants in the first generation, but there is hope, and bright hope, for the immigrants' American bred children, even if their parents be

illiterate. It is also necessary to discriminate between the man who is illiterate and the man who is uneducated. A man may be unable to read or write, and yet he may be able to mine coal, or set out grape cuttings, and trim and train the vines. This man is illiterate, but he can not be called uneducated. His illiteracy may be due to causes over which he had no control, as persecution of, or discrimination against, his race by the government under which he lived. The races which have suffered most show a high percentage of illiteracy—the Pole, the Lithuanian, and the Jew. Within seventy-five years of catholic emancipation in Ireland, and the revocation of the penal laws, illiteracy among Irish immigrants dropped from above 50 per cent. to 4 per cent. Other races have as great a hunger for education as these Irish, and meet their first opportunity for sending their children to school, after arriving in America.

Many an Irish immigrant of fifty years ago, who could neither read nor write, and who perhaps could only fix the date of his birth by its proximity to 'the night of the big wind,' became prosperous here, sent his children to school and lived long enough to see them occupy high places in the land of his adoption.

The Americanization of immigrants who do not speak English will take a longer time than was necessary for the Americanization of immigrants from Ireland, but time and American schools work wonders, and already the children of poor Russian Jews of the Ghetto can be pointed out as making their mark in the business or professional world.

The majority of the immigrants who are illiterate come here to supply the demand for unskilled labor, and the mere fact of being able to read or write in their own language would not aid them one iota in their work or make them one whit more desirable to their employers. There is often expressed a fear of the growing numbers of the illiterate laborers in this country, because of their tendency to socialism or anarchy. As a matter of fact the illiterate laborer is less dangerous from this cause than the discontented laborer of some education. The illiterate immigrant can only be reached from the public platform and the anarchistic exhorter can be easily suppressed or deported, but it is not so easy to prevent the dissemination of anarchistic pamphlets, which sow the seeds of discord and fan the flame of discontent in the heart of the laborer who can read.

Much has been written of the great proportion of criminals and paupers which is made up of aliens. In accepting statements of this character, it is well to take into consideration the fact that position in life has much to do with the tendency to commit crime, and that our immigrants necessarily begin life at the lowest rung of the ladder. Paupers and criminals will ever come in the greatest proportion from

the tenement dwellers of our crowded cities. The unfortunates, regardless of race, who are exposed to the hardships of the tenement and temptations of the slum, may be expected to furnish the largest proportion of inmates for our penal and charitable institutions. Statistics comparing the tendency to pauperism and criminality of the foreign born with that of natives, are apt to be misleading. These statistics almost invariably fail to take account of the predominating influence of sex and age upon crime. It can be demonstrated that the vast majority of criminals are of the male sex and between the ages of 20 and 45 years. The males exceed the females among immigrants in the proportion of 2.5 to 1, and about 75 per cent. are between the ages of 15 to 40. Persons less than 15 seldom are criminals and the immense number of natives below that age contribute few to the number of criminals, but help greatly to reduce the criminal average in the total native population. The great majority of immigrants, on the other hand, are of the sex and age which predispose to crime. It is also a fact that before our laws were made strict, and rigidly enforced, thousands of paupers, cripples and criminals were shipped here from Europe, and the effect of these upon our institutional statistics can be imagined, but should not be charged to the immigrant of to-day.

Even if the immigrant could be eliminated from our social problem, Utopia would not be with us. The lowly place now occupied by the foreign born, the lowest stratum of our social formation, would still exist, and would then be made up of urban degenerates or native failures from the rural districts. Idealists seem to think that the immigrant is wholly responsible for the slum with its crime and pauperism. The responsibility for the slum can be divided between money-grasping property owners and an indifferent puerile civic administration. The immigrant finds the tenements and the slums already established when he arrives and is the victim and not the cause of them.

The tendency of foreign-born towards cities, as places of permanent residence, is a well-known and widely discussed social problem. The real distribution of our immigrants is merely indicated by the destination given by newly-arrived aliens at Ellis Island, and the more accurate knowledge of their places of residence here is given by the United States census returns. Immigrants at Ellis Island may give New York as their destination, yet after a short time go to Wisconsin, Texas or Louisiana. Others destined for the far west may never proceed farther than the Atlantic seaboard, but the United States census finds them in their permanent homes, wherever they may be, from Maine to California, from Alaska to Florida. This tendency of the foreign born to crowd our large cities is not of recent development. It has been the case ever since our cities attained great size. The

percentage of foreign born in our country is not greater than it was thirty or forty years ago; in fact it can be said to be decreasing, as shown in the following tables:

Year.	Total Foreign Population.	Per cent. of Foreign Population.
1860	4,136,175	15.04
1870	5,567,229	14.44
1880	6,679,943	13.32
1890	9,249,547	14.77
1900	10,341,246	13.6

Inclination for city life is not confined to any particular race, nor to the alien alone. All races contribute to our crowded cities, some of course more constantly than others, but the best and the worst are alike fully represented. The congestion in the cities is increased also by our own native born rural population, which furnishes an ever-increasing quota to the army of city dwellers.

The great number of foreign born inmates of insane asylums throughout the country indicates that in the past too little restriction was placed on the mentally defective, and that the opportunity afforded by an inspection at the port of entrance was too scanty to be of much value. A man mentally oblique or subject to periods of insanity would, without doubt, pass the inspectors at the port of landing, if he was at that time rational and quiet. Epileptics, too, had an excellent chance of being admitted, their rejection depending on the remote possibility of their having a paroxysm while passing the inspectors. An anarchist in passing the officers would of course be docile and quiet, and his detection extremely difficult.

Mr. Goodwin Brown, attorney for the New York State Commission of Lunacy, stated before the Senate Committee on Immigration, Washington, 1902, that although only 25 per cent. of the population of the state of New York were foreign born, 50 per cent. of the inmates of the State Insane Asylum were foreigners. He also stated that this excess is not alone exhibited in New York statistics, but that an excess of 17 per cent. existed throughout the entire country of foreign born insane over the percentage of foreign born population. That these mentally defective persons were sent formerly in large numbers by persons living in Europe is scarcely open to question, but the period of government supervision of, and of power to deport, the landed alien, has been extended to two years (Act of 1903). Under this wise provision, an insane person of foreign birth, upon admission to an asylum, is investigated, and if landed within two years can be deported. The same clause covers the deportation of idiots and epileptics, so that we are now much better protected against these burdens than ever before. An additional protection is given by that part of Section 2, Law of

1903, which places in the excluded classes 'persons who have been insane within five years previous, and persons who have had two or more attacks of insanity at any time previously.'

Immigrants established years ago a reputation for bringing in epidemic diseases. They have played their part in the past in outbreaks of typhus, smallpox and cholera, but with the disappearance of the old immigrant sailing ships, the advent of the swift, clean ocean steamships and efficient modern methods of quarantine and prevention of disease, the immigrant to-day as a carrier of epidemic disease no longer causes us apprehension. The relation of the immigrant to the public health has already been discussed in an article in The Popular Science Monthly, and it is only necesary here to refer to diseases peculiar to, or prevalent among immigrants, as one of the social effects of immigration. Of these, trachoma, a contagious form of granular lids, is one of the most obstinate and destructive diseases of the eye. Oculists from all parts of the country claim that this disease was introduced by immigrants and disseminated by them, from foci of the disease, established in their tenements.

The disease is now epidemic in the poorer districts of many of our cities, but since 1897 has been one of the causes for exclusion of aliens. About the same time favus, a loathsome contagious disease of the scalp, was made a cause for exclusion. Favus is a typical immigrant disease and can not spread among persons of cleanly habits.

These two diseases, favus and trachoma, constitute 97 per cent. of the total cases of loathsome or dangerous contagious disease found in arriving aliens. After they were classed as causes for exclusion they were responsible for more determined effort to evade our laws than had ever before been exhibited. Various means of escaping inspection were resorted to, the placing of diseased steerage aliens in the cabin (cabin passengers were not inspected until 1898), the use of false naturalization papers, entrance by way of Canada or Mexico, were all employed as modes of entrance. One by one, these gateways have been closed, and with the increasing vigilance of trained medical officers at our ports and upon the Canadian and Mexican frontiers, we shall be amply protected in the future from this menace.

The ill effects of immigration upon politics are all traceable to the evils of criminal or careless naturalization. These evils are most in evidence in the large cities, but a recent investigation by the attorney general of the United States, shows that the loose administration of the naturalization laws extends to the smaller cities and rural communities as well. President Roosevelt in his message to the Fifty-eighth Congress, December, 1903, forcibly presented the picture of fraudulent naturalization and its baneful effect upon the moral health of the body politic.

The federal grand jury, recently in session in New York in relation to the naturalization of aliens, adopted resolutions condemning the wholesale manufacture and sale of counterfeit and altered certificates of naturalization, and recommended new legislation to insure uniformity of practise in the various states, an engraved certificate and other precautions to prevent counterfeiting.

Mr. C. V. C. Van Deusen, special examiner in regard to naturalization, in his report to the attorney-general, November, 1903, says in part:

The evidence is overwhelming that the general administration of the naturalization laws has been contemptuous, perfunctory, indifferent, lax and unintelligent, and in many cases, especially in inferior state courts, corrupt.

I find that it is and has been for years past the practise of judges of state courts to hold evening sessions of court at the behest of political leaders for the sole purpose of naturalizing hundreds of aliens for political purposes with a full knowledge on the part of the judges that the aliens have been bribed to become citizens and voters by the payment of their naturalization fees by the political organizations.

In those states in which the naturalization fee is not fixed by statute, or where the fees are retained by the judge or clerk, the 'naturalization business' of political organizations is a matter of competitive bidding by local courts and is awarded to the lowest bidders.

In those states which prescribe by statute the naturalization fee, which must be accounted for by the clerk, it is the general practise of political organizations to select a specific court presided over by a judge of like political faith, to which the aliens, 'rounded up' by the district workers, are sent with official cards addressed to the clerk of the court requesting that final papers be issued to the bearer. These cards are afterwards redeemed by the political organization by the payment of the amount of the fees represented by them. In many cases clerks of courts demand advance payment of these fees from the political organization, having a due regard for the fact, based on previous experience, that it is often impossible to collect the money from the political committees after an election has passed.

In many cases clerks of courts remit the naturalization fees in cases of aliens sent by their political organizations as their contributions to the campaign fund, while exacting the last cent permitted by law from aliens not 'indorsed' by such organization.

In many instances the judge passing upon the qualifications of aliens for citizenship sent him by his political organization is a candidate for reelection, the result of the election being often decided by the vote of these aliens. Under these circumstances it is not strange to find that little or no attempt is made by such judge to ascertain the fitness of the alien for citizenship and that the number rejected is practically *nil*. It is a common thing for an alien rejected in one court to be admitted in another court on the same day. In one case I found that a judge had held an impromptu session of court late at night in a railroad station while waiting for a train for the purpose of conferring citizenship upon a number of aliens whose votes were needed at an election.

In another case a judge entered an order revoking certificates of citizenship granted to seven aliens by him, under the impression that they had been sent by his political organization, but who were afterwards repudiated by that organiza-

tion. The order recited, as a reason for the revocation, the fact that the fees had not been paid.

In many instances I found that it was common knowledge that clerks of courts had issued, in the aggregate, hundreds of certificates of citizenship to aliens who never appeared in court, and afterwards forged the court records to make it appear that they had been admitted in open court.

Other clerks have furnished certificates blank as to names of aliens, but bearing the seal of the court and official signatures to members of his political organization, who have filled in the names of aliens, the clerk subsequently entering them in the court records as having been admitted in open court.

Mr. Van Deusen in summing up the situation makes the following statement and prediction: "These evils and frauds have existed for years, exist to-day, and will continue to exist and multiply until radical and stringent changes are made in the naturalization laws, and a strict supervision of their administration imposed."

It is unfair to charge to the alien the political corruption, and cheapening of the rights of citizenship, resulting from this condition of fraudulent or careless naturalization. The fault is in our laws, and to an even greater extent in the lax administration of them.

The attorney general, in his report for 1903, outlines a plan for legislation which would undoubtedly prove effective in eradicating these evils. He presents the following recommendations:

1. The omission from the statutes as they now stand of the question of intent and guilty knowledge where an offender has in his possession a fraudulent certificate of naturalization unlawfully obtained in any manner whatever, or where a fraudulent certificate so held and obtained is used for any purpose whatever. Such a change would permit prosecutions for the possession of a fraudulent certificate unlawfully obtained, or for the use of a fraudulent certificate irrespective of the intent of the oath of the applicant and witness on the certificate, which is to be regarded as presenting merely a question of fact.

2. That the law be amended so as to compel an alien at the time of applying for citizenship to present from the appropriate immigration authorities a certificate showing his age and the date of his arrival and containing also his physical description similar to that in a passport. This certificate should form a part of the court records, like his application for citizenship.

3. The petition and application and all certificates should be uniform throughout the United States, and the final certificate of citizenship issued by any court throughout the country should contain a physical description of the applicant and holder on the back thereof, for the purpose of identification and to avoid substitution.

4. The certificates should be printed in Washington under government direction, containing a watermark similar to United States obligations, and the unlawful possession of or counterfeiting of such certificates should be made an offense against the United States. The blank certificates should be distributed to the various courts on requisition, and each one should be properly numbered and recorded.

5. The power of issuing certificates of naturalization should be withdrawn by congress from the various state courts and should be restricted to United States courts.

6. All administrative matters relating to naturalization should be committed to one central government bureau.

7. It should be made a crime against the United States to sell or transfer declarations of intention, and it should be provided that after sufficient proof has been submitted to a court, establishing the fact that a certificate is fraudulent in any respect, said certificate shall be canceled of record.

These legislative suggestions of the attorney-general are as comprehensive as they are timely, and will probably be accepted by Congress as a basis for curative legislation. The card index system now employed by our immigration officials, for recording the name and date of arrival of each and every alien, could be elaborated so as to contain a physical description as well. This would prove valuable as a means of identification as outlined in the second suggestion of the attorney-general.

Economic Effects of Immigration.

The economic effects of immigration can not be accurately judged by the total number of immigrants landed each year at our ports. Hundreds of thousands go back to Europe each year, and a very large proportion of those traveling in the steerage to Europe are returning aliens. In spite of our immense total of yearly steerage arrivals, the percentage of foreign born in the United States is not increasing and is slightly less than it was ten years ago. Therefore in considering the effect of numbers, our judgment should be based upon census reports of the foreign born population. In regard to occupation and geographical distribution, we must also judge the alien after he is established here, rather than by the statement he makes to the immigration officials upon arrival. During years of industrial depression, the number of aliens returning to Europe is much increased, and while no claim is made that these birds of passage are desirable immigrants, it must be admitted that they do not add to our burdens in times of trouble by swelling the army of the unemployed. On the other hand, we have to consider the excess of males of competitive age (15 to 45) among immigrants, and their unequal distribution. Their geographical distribution is such that 86 per cent. are settled in the states east of the Mississippi and north of the Ohio rivers. Their distribution by trades or occupations is also unequal, as shown by the relatively small number engaged in tilling the soil, compared with the enormous number engaged in mining and sweat shop occupations.

One of the chief offenses charged to the immigrant is reduction of our wage standards. There are other factors more potent in depressing wages than immigration, some of which are not connected with it in any way; others are associated with it so intimately that it is difficult to separate them from it. These factors are obscured in the minds of many by the fact of our increasing immigration, and some are prone to charge the sum of their effects to immigration alone.

Cycles of business depression seem to reach us almost periodically, as they do every other country. These are hard to explain and can not be ascribed to any one particular cause.

Immigration falls off very noticeably during these periods, and, in addition, the stream of aliens leaving our ports for Europe is vastly increased. During such periods of industrial depression the wages of the toiler are necessarily reduced. It is not an oversupply of immigrant labor which is responsible for the stagnation, but an unwillingness on the part of the capitalist to invest money in enterprises whose success is doubtful, owing to commercial uncertainty. It is not a lessening of demand, owing to over supply, but often a complete absence of demand for labor, with abandonment of all attempts at production, due to lack of confidence in financial conditions.

The influence of improved machinery upon wage depression can not be over estimated, although its introduction is closely associated with immigration. Improved machinery would probably have been introduced and would have had its effect upon wages in the entire absence of immigration. The use of improved machinery made possible the employment of thousands of unskilled laborers under the direction of a few skilled workers, where formerly the work was done entirely by skilled laborers or mechanics. Its use immensely increased the power of production, and created a new demand for unskilled labor. The effect of machinery has been felt upon wages in the textile trades, woodworking, steel and iron industries, soft coal mining and other occupations. The advent of improved machinery was inevitable, and no labor organization, however strong, could indefinitely clog the wheels of progress by postponing its employment. The immigrant is not responsible for its introduction, for it has been introduced in countries with no immigration problem. He simply took advantage of the demand for labor thus created and played no small part in the wonderful growth of our mining and manufacturing industries. His coming no doubt facilitated the introduction of improved machinery, and it is probable that without this unskilled labor our present position as a producing power would not have been reached for many years to come. The employment of women and children in textile, leather and tobacco trades has demoralized the rate of compensation for male workers in those occupations. Many immigrant women and children take advantage of this practise, but it existed before the immigrants were employed in this way, and to-day thousands of native women and children are employed in factories and mills, especially in the south. The practise is here to stay, and beyond the limitation by law of the age of child workers, can not be stopped. The immigrant's wife and children are not responsible for it, but by means of it increase the family earnings and raise their standard of living.

A depressing influence upon wages is exerted by the competition of the rural factory or shop. The manufacturer in the rural community often receives a bonus, exemption from taxes, free water or other inducements from the municipality. He finds abundance of cheap labor, men, women and children, who can afford to work below the wage scale of the city, because of the lower cost of living. He is thus enabled to place his products upon the market at a cost much below that of the city-made product, and to compete with him the city manufacturer is forced to reduce his wage scale. This competition of the rural shop or factory is felt in tobacco, cotton, silk, leather and many other industries. Many of the industries of the south are of a similar competing character. The wages paid, the standard of living and cost of necessaries are all much below those of the North. This cheap native labor of the south is felt most as a competing factor by the textile industries of New England, who are forced to secure cheap labor for their own salvation.

The difficulty of maintaining efficient labor organization is the cause ascribed by many labor leaders for wage depression. In this difficulty the immigrant has played an important part. The failure of the strike of 1875 in the coal mines, and of the great Homestead strike in the steel and iron industry, is explained by the introduction of alien labor. After years of effort the aliens in the mining fields have been organized successfully and are now, for their own betterment, heart and soul in the movement for living wages. The cheap native labor in the soft coal mines has caused the organizer much more trouble than the alien laborers.

Most of the skilled trades are able to maintain their unions and their wage-standards in spite of foreign immigration. In some occupations, however, the stream of skilled alien addition is so great and so constant, that disorganization and confusion result in the trade, and wages drop to a minimum. In this confusion and disorganization caused by the influx of foreign skilled labor, the clothing trade suffered more than any other industry. So constant has been the stream of foreign tailors to this country that they have now almost monopolized this occupation. The wage scale has descended to a point where the American can no longer compete, and he has been finally forced out of the business as a workman. A revolution has taken place in the manufacture of clothing. The wholesale manufacture of ready-made clothing has superseded the output of the individual tailor shops. Under the present system of wholesale manufacture of ready-made clothing, the work is subdivided into many branches. Formerly a tailor made and completed the garment himself, by reason of skill which it took four or five years to acquire; now the garment passes through the hands of a dozen or more workers, who are each skilled in some particular

branch of the industry. Their skill is acquired in a few months, and they can only do certain kinds of work. This subdivision of labor makes it possible to train and employ almost at once the thousands of new arrivals, and out of the employment of these new arrivals and the conditions resulting from their ever increasing competition arise the sweat shop and its evils. The sweating system produces a condition of affairs in which the operative performs the maximum amount of work for the maximum wage, the length of his working day only limited by his endurance, and, even when he extends himself to the limit, in many cases he can earn scarcely enough to keep him from starvation. This work in addition is performed under the most unsanitary conditions, often in the foul vitiated atmosphere of tenement rooms which are used alike for working, eating and sleeping.

Effective organization is difficult, well-nigh impossible among these clothing workers because of the influx of new arrivals and the employment of women and children in the so-called home work. Legislation has done much to ameliorate sweat shop evils. The workshop in the home is seen much less frequently than formerly, and is fast disappearing. A certain amount of work upon clothing will inevitably be done at home, called 'finishing,' by women who are not entirely dependent upon it, but who increase the aggregate earnings of the family in this way. Much of the work in the clothing trade is now done in shops, especially fitted for the purpose. These shops are more amenable to inspection under our factory laws, and a great deal has been done by state inspectors in this direction.

Another institution charged to immigration, of which we hear almost as much as we do of the sweat shops, is the so-called 'padrone system.' The padrone system is simply the extortion practised by unlicensed Italian employment agents, who, by their knowledge of our language, are in a position to oppress their credulous, ignorant fellow countrymen in a variety of ways. The worst features of the system have been eliminated through the enforcement of our laws, and the remnant of the system would disappear if the Italian immigrants could be distributed to the rural districts, instead of being at the mercy of padroni in the crowded Italian quarters of our cities.

It will be seen that the competition of the newly arrived unskilled laborer with native Americans is indirect. He competes directly only with other alien laborers, who are already settled in the country. On the other hand, the alien skilled laborer competes directly with native Americans. In some trades the foreign arrivals who are skilled come singly or in small groups, and can be taken into the labor organizations without trouble and no reduction in wages results, but when the stream of skilled arrivals of any particular trade is of large size and constant, organization is impracticable. The new arrivals have to

meet in turn the competition of the thousands of the same caliber and often of the same race, who follow close on their heels; demoralization results and wage reduction is inevitable.

The establishment here of foreign standards of living is unquestionably detrimental. The immigrant is tempted by the wages paid laborers here, which are four or five times greater than those paid laborers in Europe; but when he lands here he finds that not only is the class of food which he used in Europe more costly, but that he must increase his dietary to enable him to perform the work required of him. To withstand the strenuous effort, and the output of energy essential to American industrial life, the alien requires meat and other nutritives, in addition to the fruit and vegetables which sufficed for him at home. If he does not thus fortify himself for the struggle he will break down under the strain. The standard of living among immigrants is of course below American standards, but it is being constantly elevated, with a rapidity, among our alien population as a whole, in inverse ratio to the increase of yearly arrivals. Among individual families the elevation of the standard of living keeps pace with their Americanization and their success in life. The immigrant's daily contact with Americans, coupled with the ideas absorbed by his children in American schools, is a potent factor in raising this standard.

GALILEO.

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I.

When the position of a heavenly body changes with such extreme slowness as to leave astronomers undecided as to the change even, and still more as to the direction of the change, it is their custom to compare two observations made at a great interval of time. If the doubt still exists, they affirm with certainty that the position they have measured is invariable, or nearly so, since it is subject to no regular and persistent alteration. Such a method applied to the history of the human mind leads to grave melancholy and discouragement. Men have been ignorant and blind at every epoch. Always we find the same ignorance, the same rash illusions, the same obstinate prejudices.

Toujours mêmes acteurs et même comédie.

Three centuries before our era, a philosopher, Cleanthes, demanded that Aristarchus should be brought to justice for his blasphemies in declaring the earth in motion, and the sun to be the fixed centre of the universe. Two thousand years later, the human understanding had not progressed. The desire of Cleanthes was realized, and Galileo was accused of blasphemy and impiety, in his turn. A tribunal dreaded by all condemned his writings, constrained him to denials disavowed by his conscience, and, judging him unworthy of a freedom that he had abused, deprived him of a part of it, and thought it an indulgence to have left him any liberty whatever.

But history is not to be judged in this way. Events in themselves are of small moment; the impression that events produce is the only revelation of the public consciousness. Never before has its generous aversion for intolerance burst forth so strongly as for the sufferings of Galileo. The story of his misfortunes, exaggerated like a pious legend, has confirmed the triumph of the truths for which he suffered, at the same time avenging him. The scandal of his condemnation will forever vex the pride of those who still wish to put down reason by force; and the just severity of opinion will preserve the unwelcome remembrance as an eternal reproach. But it is necessary to be frank: this great lesson did not cause any deep sorrows. The long life of Galileo, taken all in all, is one of the most peaceful and most enviable that the history of science records.

The foregoing paragraphs translated freely from the life of Galileo by M. Bertrand, perpetual secretary of the Paris Academy of Sciences, expresses so precisely the point of view of this article that I have quoted them in order to have, from the outset, the support of his great authority. And to them may be added the following extracts from the 'History of the Inductive Sciences' of Dr. Whewell, master of Trinity College, Cambridge. The words in brackets are my own.

The heliocentric doctrine has for a century been making its way into the minds of thoughtful men on the general ground of its simplicity and symmetry. Galileo appears to have thought that now, when these original recommendations of the system had been reenforced by his own discoveries and reasonings, it ought to be universally acknowledged as a truth and a reality. And when arguments against the fixity of the sun and the motion of the earth were adduced from scripture, he could not be satisfied without maintaining his favorite opinion to be conformable to scripture as well as to philosophy; and he was very eager in his attempts to obtain from authority a declaration to this effect. The ecclesiastical authorities were naturally averse to express themselves in favor of a novel opinion, startling to the common mind, and contrary to the most obvious meaning of the words of the Bible; and when they were compelled to pronounce, they decided against Galileo and his doctrines. He was accused before the Inquisition in 1615; . . . the result was a declaration of the Inquisition that the doctrine of the earth's motion [was] contrary to the sacred scripture. Galileo was prohibited from defending and teaching this doctrine in any manner, and promised obedience to this injunction [as will be shown later].

But in 1632 he published his Dialogues and in these he defended the heliocentric system by all the strongest arguments which its admirers used. Not only so, but he introduced into this dialogue a character under the name of Simplicius [supposed by contemporaries to have been intended to represent the Pope then reigning, which idea was fully accepted by the Pope himself, especially as the Pope's own words were attributed to Simplicius,] in whose mouth was put the defense of all the ancient dogmas and who was represented as defeated at all points of the discussion; and he prefixed to the dialogue a notice To the Discreet Reader, in which, in a view of transparent irony he assigned his reasons for the publication. . . . The result of this was that Galileo was condemned for his infraction of the injunction laid upon him in 1616; his dialogue was prohibited; he himself was commanded to abjure on his knees the doctrine he had taught; and this abjuration he performed.

. . . The general acceptance of the Copernican system was no longer a matter of doubt. Several persons in the highest positions including the Pope himself [not the Pope] looked upon the doctrine with favorable eyes; and had shown their interest in Galileo and his discoveries. They had tried to prevent his involving himself in trouble by [through] discussing the question on scriptural grounds. It is probable that his knowledge of those favorable dispositions towards himself and his opinions led him to suppose that the slightest color of professed submission to the church in his belief, would enable his arguments in favor of the system to pass unvisited; the notice [To the Discreet Reader] in which the irony is quite transparent and the sarcasm glaringly obvious, was deemed too flimsy a veil for the purpose of decency, and, indeed, must have aggravated the offence.

The foregoing extracts from the writings of authoritative historians of science place the chief events of Galileo's long life in what seems to be the true light. There is little doubt as to the events themselves—except in a single particular, which will be considered in what follows. Much controversy has raged over their interpretation. They must be considered in two regards: First, in respect of Galileo's private and personal experience; second, in respect of the lesson which that experience has taught to the world in general. The remark of Bertrand

that has just been quoted is profoundly significant: *events in themselves are small affairs; it is their effect on the public consciousness that remains and is permanent.* Galileo's private life was essentially peaceful, as a whole even 'enviable.' To the world in general he is, on the other hand, the protomartyr. His trials have opened new roads for human thought, given liberty to science and philosophy, and were the occasion of a final delimitation of the provinces of the church and of philosophy. The modern attitude of mind may be said to take its date from him. It is in this that his greatest service to mankind consists. The astonishing discoveries that we owe to his genius are small matters in comparison.

In what follows the events of his life will be recited. Where there is doubt it will be pointed out. There is no space to discuss controverted points at length. Volumes have already been written on the history of his trial by the Inquisition; on the documents, genuine or fabricated, of this process; on the question whether or no he was put to the torture.* To these volumes reference must be made, once for all, for the original documents and for a discussion of their authenticity. The object of the present chapter is, first, to tell the story of his life, second, and most important, to exhibit its effect upon his own and succeeding centuries. It will conduce to clearness if his private and personal life be separated in thought from his services to mankind in general; if the story of his experience be discriminated from the legend.

The popular legend in its crudest form declared that Galileo, a martyr of science, languished in the dungeons of the Inquisition; defended his doctrines boldly; was tortured; and under bodily torture recanted and abjured; saying, however, at the last, *E pur si muove* before he was again removed to his prison, where his eyes were blinded. If the legend had not taken on this crude shape it would, perhaps, have been less efficacious in the century immediately following his death. As it stands it is almost entirely devoid of truth. The real history is hardly less distressing, but the facts are utterly different.

Galileo was born at Pisa on February 18, 1564, of the noble family of the Bonajuti which since 1343 had been known as the Galilei. In 1445 a representative of the family was Gonfalonier of Florence, and no less than fifteen of its members had served in the Signoria. The father of Galileo, Vincenzio, was skilled in mathematics and especially in music, on which he wrote several treatises. He was poor and

* Among these the reader may wish to consult Martin, 'Galilée, etc.,' 1868; Wohlwill, 'Der Inquisitions Process des Galileo Galilei, etc.,' 1870; L'Epinois, 'Galilée, son procès, etc.,' 1867; Gebler, 'Galileo Galilei, etc.' (English edition), 1879; Galileo, 'Opere, edizione nazionale,' 1890–8.

wished his brilliant son to adopt the lucrative profession of medicine. Galileo's early inclinations seem to have been to become a painter. The boy was educated at the monastery of Vallombrosa, where he learned Latin, some Greek, a little logic. He was an excellent pupil, but as his eyes were affected his father removed him and, at the age of seventeen (1581), sent him to study medicine at Pisa. He was already a clever musician, witty, eloquent, with a strong talent for painting, and had laid the foundations of a literary style which Italians estimate highly. In his later years Galileo knew the poems of Ariosto by heart. His general health was not good, but he was amiable, gay, versatile, fond of society and also very fond of a country life and of his vineyards and groves. He was considerate and liberal to his family, devoted to his children.* His friends loved him ardently, and his enemies were equally constant in their dislike. The characteristics of his maturer life were in evidence throughout his youth also. His powers of observation were extraordinarily quick. He was a philosopher, also, from the first, and very expert in all mechanical matters.

Before the high altar of the cathedral at Pisa hangs a lamp,—a masterpiece of Maestro Possenti. Watching its swingings to and fro one day Galileo, then a student, observed that although the amplitude of the swings diminished the time of oscillation remained the same (1583). From this chance observation resulted the law: The time of oscillation of a pendulum is independent of the amplitude of its swings. If this be true (and it is true when the amplitudes are small), the pendulum can be used to measure, with precision, intervals of time. A hundred of its swings will always require the same time whenever the arc of swinging is not large. The first application of this discovery was the invention of a pendulum suited to measure pulse-beats. Towards the end of his life Galileo endeavored to construct a pendulum clock. He was engaged in this research at the time of his death, aided by his son Vincenzio, who carried on the work. A short pendulum beats more quickly than a long one. The law of the relation of length to period was also discovered by Galileo. It is: The lengths of pendulums are proportional to the squares of the times of oscillation. A pendulum beating seconds is four times as long as one beating half-

* Galileo was never married. He formed an illicit connection with a Venetian woman, Marina Gamba, by whom he had three children, two daughters and a son. His daughters took the veil in a convent at Arcetri. His son married and left descendants. The mother of his children subsequently married one Bartolucci, with whom Galileo was in friendly relations after the marriage. In 1627 Pope Urban VIII. granted a pension to Galileo's son who did not accept it, owing to religious observances necessitated by the grant. The pension was transferred to a nephew and finally it was increased and bestowed upon Galileo himself with the condition that he should adopt the tonsure. This pension was drawn by Galileo till his death.

seconds, therefore. These laws are the basis of horology. They were first fully utilized in the construction of clocks by Huyghens.

A lesson in geometry overheard by Galileo while a pupil excited his deepest interest. Euclid soon became his master and, from this day, his attention to medicine slackened, much to his father's regret. The salaries of mathematical professors were extremely small in those days, while the rewards of successful physicians were very much greater. Owing to his father's poverty, Galileo was withdrawn from the university in 1586, and returned to Florence. It is recorded that at the university he was known as a brilliant, though disputatious, pupil, and was nicknamed 'The Wrangler.' At Florence he lectured before the academy on the situation and dimensions of the Inferno of Dante—a question partly philosophical, partly scientific. It was at this time that he studied the works of Archimedes and wrote a little treatise on the hydrostatic balance. In 1587 he went to Rome and made the acquaintance of Clavius and other scientific men.

In 1588 he had the great good fortune to meet a generous patron, the Marchese Guidobaldo del Monte, and, in the same year, wrote at his request a treatise on the center of gravity of solid bodies. By his influence Galileo was appointed to be lecturer on mathematics in the University of Pisa (1589). His salary was only sixty scudi annually (about $65), and he was obliged to eke it out by giving private lessons. The salary of the professor of medicine was 2,000 scudi. During the years 1589 to 1591 he made those experiments on falling bodies which are the basis of the science of mechanics.

From the time of Archimedes (287–212 B. C.) till that of Leonardo da Vinci and Galileo there had been no progress in theoretical mechanics. Archimedes discovered the theory of the lever: 'Give me where I may stand and (with the lever) I will move the world.' His knowledge of practical mechanics was, no doubt, derived from his famous works of military engineering. All the great buildings of antiquity had been built by processes not unfamiliar to him. All the great basilicas of Europe and all the Gothic cathedrals with their nice system of balanced thrusts had also been erected before the time of Leonardo. The practical processes of engineering were highly developed, therefore, but as yet no one had formulated a theory. That Leonardo comprehended its fundamentals is abundantly shown by his note-books recently published. Every military engineer who had watched the flight of a projectile was aware that the received notions of mechanics would not explain its motions. No theory of the impact of such projectiles had even been proposed. A whole science was to be created. The doctrine of mechanical equilibrium is statics—and this science was founded by Archimedes. The doctrine of mechanical motion is dynamics—and nothing was done in this science till the time of Galileo.

The theories of the lever, of the inclined plane and of the screw were familiar to Leonardo.*

The ideas of Aristotle as to motion and rest were not physical, but metaphysical. An example will illustrate his mode of reasoning which satisfied the scientific world for something like two thousand years. When a stone is thrown from the hand why does it continue to move for a time, and why does it eventually come to rest? Where is the cause of motion—in the hand?—or in the stone? If in the hand, how can the stone continue to move after it has left the hand? If in the stone, why does it ever come to rest? Aristotle's answer is that 'a motion is communicated to the air, the successive parts of which urge the stone onward; each portion of the air continues to act for some little time after it has been acted upon, and the motion ceases when it comes to a particle which can not act after it has been acted upon.' The confusion of this explanation is complete.

The mechanical ideas of Aristotle and of his successors, as to falling bodies, are expressed in these words: 'That body is heavier than another which, in an equal bulk, moves downward quicker.' Transforming the phrase, we may say, that if two bodies, *A* and *B*, are of equal bulk but of different weights, then the heavier body will fall the quicker; or, again, if *A* weighs ten pounds and *B* one pound, *A* will fall faster than *B*. The Aristotelians of Galileo's time further maintained that *A* would fall exactly ten times faster than *B*. Galileo's experiments proved that they fell in precisely the same time. Sixteen hundred years earlier Lucretius had come near to the same truth: "For whenever bodies fall through water and thin air they must quicken their descents in proportion to their weights, because the body of water and subtle nature of air can not retard everything to an equal degree; on the other hand, empty void can not offer resistance to anything in any direction at any time, but must continually give way; and for this reason all things must be moved and borne along with equal velocity, though of unequal weights, through the unresisting void."

While Kepler was determining the empirical laws according to which the planets move in their orbits, Galileo was laying the foundations of the science of mechanics by which, eventually, Newton was to explain why they so move. The foundations of mechanics rest on experiments made by Galileo, at Pisa, on the laws of falling bodies. It was the opinion of the time that heavy bodies fell faster than light ones, and it was a matter of common observation that a square foot of wood reached the ground before a square foot of paper released at the same time. The fact was explained by Galileo as due to the resistance of the air. In a vacuum they would fall at the same time. By crump-

* Leonardo's investigations in mechanics were not published during his lifetime, but a correct theory of the lever was known to him as early as 1499.

ling the paper into a solid ball, it could be made to fall as rapidly as a ball of wood or iron. Experiments of this nature led Galileo to the discovery of the first law of motion, to wit: The velocity of falling bodies varies directly as the time.

At the beginning of the fall the velocity is zero; at the end of the first second, it is a certain quantity which experiment shows to be the same for all bodies. Let us call this velocity g. Galileo's experiments showed that at the end of the second second the terminal velocity was $2g$, at the end of the third, $3g$ and so on. The algebraic expression of the first law is, then,

(I.) $$v = g.t$$

(experiment shows that $g = 9.81$ meters approximately).

The second law of motion refers to the relation of the spaces through which the body falls in different intervals of time; it is: The spaces through which a body falls vary as the squares of the times. All bodies obey this law, also, no matter of what materials they are made up.

(II.) $$s = \tfrac{1}{2}\, g.t^2$$

($s =$ space, $t =$ time).

At the beginning of the fall the time (t) is zero, and the velocity (v) is also zero. At the end of the first second, $t = I$ and $v = g$ (by I.). The velocity has increased from 0 to g and its average value is therefore $0 + g/2 = \frac{1}{2}\, g$. The space traversed at the end of the first second is (by II.) $\frac{1}{2}g$; at the end of the second second, $2g$; at the end of the third second, $\frac{9}{2}g$, and so on. The two laws are not independent but are separated for convenience. They are sometimes united into one, and the law of inertia (also known to Galileo) added in this form: Every body preserves its state of rest or of uniform motion in a right line unless it is compelled to change that state by forces impressed thereon.*

It is this latter law that changed the whole face of science. It was supposed by the ancients and by Copernicus that the normal condition of all bodies was rest; that if they were moving it was because some force was perpetually impelling them. On the earth a pendulum stops because of the resistance of the air and the friction at its supports. Remove the air and annul the friction and it will swing forever until some impressed force stops it, so Galileo announced. Kepler was incessantly trying to conceive how a planet could continue to move in its

* The statement of the law is Newton's. It is implicit in Galileo's laws of falling bodies and must have been understood by Leonardo da Vinci. Kepler, perhaps, anticipated Galileo in its discovery. It is a necessary part of Huyghens's theory of central forces, but it was not clearly enunciated until the day of Newton.

orbit, and was forced to conclude that some inherent energy, perhaps an angel, perpetually acted to keep it moving. Galileo's law announces that if it is once set in motion it will continue to move until some impressed and extraneous force causes it to stop. Motion is as 'natural' as rest, therefore. It happens that on the earth there is no body moving under the action of no force. Falling bodies, projectiles, and the like, are perpetually attracted by the earth's mass, continually retarded by the resistance of the air. It required abstract philosophical reasoning to determine how such bodies would move were the impressed forces removed, and it is this reasoning that is Galileo's chief title to enduring fame. In this respect he changed the whole thought of the world. His telescopic discoveries might have been made by others. There was no man in Italy besides himself who could have founded the new science of mechanics.

Newton added two laws of motion which read: The alternation of motion is ever proportional to the moving force impressed and is made in the right line in which that force acts. To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and in opposite directions. His law of universal gravitation is: Every particle of matter in the universe attracts every other particle with a force directly as the masses of the two particles, and inversely as the squares of the distance that separates them.

With these laws as bases of calculation the question may be answered: What orbit will a planet describe about the sun? The answer is, a conic section, an ellipse for example. Again: What will be the law of the motion of each planet in its ellipse? The answer is: Its radius-vector will sweep over equal areas in equal times. Again: In a system of such planets, how will their orbits be related? The answer is: The squares of their periodic times will be proportional to the cubes of their mean distances from the sun. From the single law of gravitation the three laws of Kepler (as above) necessarily follow. Kepler's laws were empirical and were not complete until Newton's discoveries. This brief note explains the logical outcome of Kepler's and of Galileo's researches.

The new laws of motion were expounded to the students of Pisa with fire and eloquence. The theories of Aristotle and of his followers were treated with scorn and contempt. In his zeal for the truth Galileo branded the scientific errors of his colleagues almost as if they had been moral faults. His asperity laid the foundation of enmities that followed him throughout the whole of his life and led to his ruin. It is as true of Galileo as of Roger Bacon that his character was his fate.

How the strictures of Galileo were received by the exasperated Aristotelians may be imagined. If his experiments were to be believed, the words of Aristotle were false. If the philosophy of Aristotle were false in one part it might be false in all. The experiments must therefore be denied, and their author discredited. It is recorded that the experiments were, in fact, denied. The facts of experience were met

with argument. Galileo's retorts were bitter and brilliant, his sarcasms searching and unsparing. Before the end of his three years' engagement as professor had expired, he had involved himself in a hopeless wrangle with his colleagues and with Aristotelians throughout Italy. An imbroglio with John of Medici put him out of favor at court also at this very time. The nephew of the reigning Duke of Florence had invented a machine for dredging the harbor of Leghorn, and the plans were submitted to Galileo, who declared the apparatus to be useless, as indeed it was. He made no friends by this candor and gave another weapon to his enemies which they were not slow to use. The students in the university were incited against him and he was publicly hissed at lectures, so that he felt it advisable to resign his professorship (1591).

He returned to Florence discredited and out of favor. His father died in July of this year, leaving his family in distress for money. Galileo's friend and patron, the Marquis del Monte, warmly recommended him to his friends in Venice, and as a result he was appointed to be professor of mathematics at the University of Padua, for a term of six years, this time at a salary of 72 zecchini, about $90. He remained titular professor for a period of eighteen years, until 1610, his appointment being three times renewed and his emoluments increased to $500. In December, 1592, he entered upon his duties. His lessons embraced a wide range of subjects: astronomy, gnomonics, fortification, mechanics and the like. His lectures were thronged with students. The halls were not spacious enough to hold them all and at times he taught in the open air.

In 1597 he invented his proportional compasses of which he was very proud. His manuscript description of them was plagiarized by one Balthasar Capra, and Galileo's scathing review of the work excited general notice for its bitter satire. He was already recognized as an adversary to be feared.

It has lately been demonstrated that we owe the invention of the thermometer to Galileo. His first instrument appears to have been a crude air thermometer devised in 1595. It was soon (1611) applied by physicians to the diagnosis of fevers and about 1641 to regular meteorological observations of temperature. The scales were arbitrary. The idea was developed by his pupils in various ways. The 'Florentine' thermometers used by the Accademia del Cimento (1657–1667) had straight sealed tubes connected with bulbs filled with spirits of wine. The highest summer heat corresponded to 80°, the lowest winter cold to 20°. So late as 1741 Florentine thermometers were in common use throughout Europe. It was not till 1694 that the freezing and boiling points of water were *proposed* as standard. Fahrenheit's thermometer date from 1709, Réaumer's from 1730, Celsius's (the centigrade) from 1742–3.

In 1604 a new star suddenly appeared in the heavens. It was discovered in October and quickly grew to be brighter than Jupiter. By the end of March, 1605, it had diminished to the brightness of a star of the third magnitude and in about a year it had vanished from sight. Its career was like that of the new star of 1572—Tycho's star. Galileo delivered three lectures on the new star to crowded audiences. He enforced upon the Aristotelians the conclusion that the heavens were not incorruptible, as they maintained. Here was a glaring proof of it. The star had no parallax. Hence it was far beyond our atmosphere. It was no 'meteor,' as they also maintained. These just conclusions were advanced with rasping criticisms of the old philosophy and the breach with his colleagues was widened still further.

In 1597 Kepler sent his *Prodromus* to Galileo, who writes to thank him for it, saying:

> I count myself happy, in the search after truth, to have so great an ally as your self. . . . I have been for many years an adherent of the Copernican system. . . . I have collected many arguments for the purpose of refuting (the commonly accepted hypothesis), but I do not venture to the light of publicity for fear of sharing the fate of our master Copernicus, who, although he has earned immortal fame with some, yet with very many—so great is the number of fools—has become an object of ridicule and scorn.

It is to be noticed that Galileo (like Copernicus himself) dreaded the ridicule of fools. It is probable that neither of them feared the discipline of the church, or even considered it likely to be exerted.

The revolution in men's ideas to be worked by the Copernican system was not understood in the sixteenth century. It was regarded as a scientific hypothesis—an absurd one, contrary to scripture, Tycho Brahe had said. Its theological import was appreciated first by Lutherans and afterwards in Italy. Pope Paul III., to whom Copernicus dedicated his book in 1543, received it 'with pleasure.' A second edition was printed in 1566 without exciting the slightest adverse remark. It was not until the time of Galileo that men began to see that the accepted order of heaven and earth was inverted by the new doctrine. The earth was no longer the center of the universe. The planets were not made for man, who was dethroned not only in science, but in philosophy and theology as well. It remained for more modern times to appreciate that as it was by man himself that man was so dethroned, a new glory had been added to his crown.

All men find it painful to face novel ideas, and it is but natural to seek and find sufficient reasons for avoiding painful thoughts. When they are once familiar, new pleasures are discovered; and not until then do they begin to gain acceptance. Kepler 'shuddered' at the very idea of an infinite universe. Even he had not completely shaken off the Ptolemaic conception of a limited world. The authority of the

Roman Church had been in theory literally universal, and Copernicus limited its world to one small planet, not so large as Jupiter as Galileo showed a few years later. The new doctrine disgraced the dignity of the earth among the planets. The authorities of a universal church could not but feel that their own dignities were attacked by the same blow. Arguments against the scientific truth were forthcoming from every chair of philosophy in Italy, and every theologian could successfully defend the literal sense of Holy Writ against such subtile and wire-drawn interpretations as were subsequently advanced by Foscarini and Galileo. I imagine the state of mind of their more intelligent contemporaries to have been one of interested bewilderment. The less intelligent were repelled and offended. The mass of pious christians was outraged and indignant. The Pope (Urban VIII.) and most of the cardinals sincerely believed that incalculable injury would result to the church from the promulgation of an opinion flatly contradicting the literal words of scripture. It was not until the discoveries of the telescope came to confirm the hypothesis of Copernicus that all these questions were pressed home for decision.

(*To be continued.*)

RADIOACTIVITY AND MATTER.*

BY CLEMENS WINKLER.

THE discovery of radioactivity has opened to physical and probably also to chemical research a field of extraordinary and peculiar promise. We seem to have a source of energy which flows spontaneously for unlimited time without tangible indication of its source; effects of energy are exhibited which neither in essence nor in phenomena resemble those previously known; substances are presented which seem to be of an entirely new kind, though they resemble our oldest and best-known elements so closely as to make their distinction difficult. The most prominent of these substances is radium, which, in the opinion of its discoverers, may be considered a new chemical element and which has been recognized as such by the International Atomic Weight Committee by giving it a place in their table of atomic weights for 1904.

Much more indefinite are the relations of the other radioactive substances thus far made known. The existence of polonium, discovered by P. and S. Curie, was for a time considered dubious, but seems to awake to new life in the radiotellurium of W. Marckwald. On radiolead voluminous researches have appeared which are especially noteworthy in chemical respects, still they do not yet authorize us to recognize a new element with certainty, even if we disregard the objections raised by F. Giesel against these researches. The same may be said of the actinium of A. Debierne and other radioactive substances, such as are supposed to have been detected in the earths of the cerium and yttrium group.

This uncertainty may be understood if we consider that for the researches thus far made only very small amounts of pure or merely enriched materials have been available, which has made the chemical investigation very difficult. The great fascination of tracing the observed phenomena of radioactivity by means of the sensitive photographic plate, the electroscope and the phosphorescent screen had quite naturally made the investigation of the chemical behavior of the substances in question a secondary matter which, while it has not been entirely overlooked, yet has not received that degree of attention that formerly was bestowed on the determination of the characteristic properties of newly discovered elements.

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* Translated from *Berichte der Deutschen Chemischen Gesellschaft.* The author, best known by this discovery of the rare element *Germanium,* died Oct. 8, 1904, at Dresden.—G. D. H.

In the rather simple working up of the raw material containing radium, the treatment of barium has in the main been followed. Subsequently, the utilization of certain differences in solubility has permitted fractional crystallization and we have thus learned of a special spectrum of radium. But it is questionable whether the spectrum reaction can claim a decisive weight. For a substance, which in so minute proportions has been extracted from so complex a material as the residuals of Joachimsthal, the spectrum might readily prove deceptive. There seems to be very little correspondence between the spark-spectrum for radium obtained by Demarçay, and the flame spectrum described by F. Giesel, while the reddish-orange lines in the radium bromide spectrum, as well as the red coloration which this substance imparts to the flame, make it not impossible that some alkaline earths may have remained in the final residue examined. Besides, no radium compounds have been sufficiently investigated, nor have any chemical reactions been detected specifically peculiar to radium. The determination of its atomic weight has been decisive in recognizing radium as a distinct element, especially as this atomic weight was found to be exceptionally high.

Radium lead has been examined chemically more thoroughly, and yet no noteworthy differences have been discovered between its reactions and those of common lead. Only a great difference in atomic weight seemed to exist. The atomic weight of radiolead was determined by ascertaining the amount of sulphuric acid in its sulphate. It was found to contain 41.85 per cent. of SO_4, while lead sulphate contains only 31.71 per cent.

Assuming that radiolead is quadrivalent like thorium and uranium, its atomic weight from the above analysis would be 260.2, that of lead only 206.9. But this determination seems of doubtful correctness, because the sulphate obtained has not been heated to a beginning red-heat, but has only been dried to 400–420 degrees. At so low a temperature experience has shown it is impossible to remove all adherent sulphuric acid, so that it is not strange that a higher per cent. of sulphuric acid remained. The atomic weight of radiolead can not be deduced from such determinations. Also the supposed discovery of other elements (such as the much hunted for ekamanganese of Mendelejef) can not be established upon the result of such faulty determinations.

Indeed the chemical researches made can not be considered sufficient, however much we may admire the other researches made on the radioactivity of matter. Even the results obtained by fractioning can only be used with extreme caution, because they may lead easily to false conclusions. When the discovery of spectrum analysis had excited the scientific world as it is to-day excited by that of radioactivity, it was

seriously supposed that calcium had been decomposed, because the green line of its spectrum had been made to disappear by fractioned precipitations of its chloride, and crystallographers on this ground tried to find reason for the extraordinary richness of the crystal forms of calcite. Similar pardonable errors may also occur in other cases, though we do not mean to assert that such errors have actually been committed in the fractioning of radioactive substances.

But we must be permitted to ask whether it is really justifiable to assume the presence of a new element in a substance for the sole reason that this substance is radioactive. It would certainly be surprising if every one of the numerous, long known chemical elements, which show radioactivity, were to contain also an elementary associate of almost exactly the same chemical character. Against such a supposition we can mention many reasons, entirely independent of the fact that such a supposition is in conflict with all general experience and the hitherto unshaken idea of the nature of chemical elements. Uranium—one of the elements in question—is certainly a typical element, yet, according to William Crookes, it can be separated into an active and a non-active fraction by merely treating its hydrous nitrate with ether, or by fractional crystallization or by fractional ignition—and at the same time these fractions are said to show no chemical differences whatever. Béla v. Lengyel who doubts the existence of radium, succeeded in making barium active by heating its nitrate with uranylnitrate, and Henry Becquerel prepared a strongly active barium sulphate by precipitating by sulphuric acid a barium chloride solution to which uranyl chloride had previously been added; in this case the activity of the uranium compound had at the same time diminished. Further K. A. Hofmann and E. Strauss have obtained inactive fractions from active uranium compounds; on the other hand they succeeded in temporarily withdrawing from uranium its activity by means of barium or bismuth compounds. Especially remarkable are the experiments of A. Debierne, which have been conducted in a similar manner with actinium, and by which it was proved that it is easy to make active the compounds of barium so that they scarcely differ from those of radium, except that they do not give a radium spectrum. The active barium is said to stand between barium and radium, its anhydrous chloride is self-luminous like that of radium, and may equally well, by fractional crystallization, be separated in a more active and a less active portion.

By induction alone such remarkable phenomena can hardly be accounted for. The objection raised by F. Giesel against Béla v. Lengyel, namely that the activation of barium first produced by the latter might be due to some radium contained in the uranium salt used, is disproved by the fact stated, that under other conditions the same result even in a much higher degree was obtained.

And what are we to say of the supposed material emanation of radioactive 'elements,' of their instability, of their decomposition by splitting off of helium and of the decomposition of the elements themselves? Until now there has not been furnished any demonstration whatever that elements of high atomic weight, to which gold and platinum certainly must be counted, are polymers of elements of lower atomic weights, and that they decompose into such. The idea of a chemical element in the old sense remains still unshaken, and it will require much more thorough chemical experimental research than those produced thus far, to disturb it. On the contrary, it appears from day to day more plainly, that radioactivity seems to be extremely widely distributed, and this observation leads us to the question whether radioactivity may not be simply a purely physical phenomenon, which may be exhibited by matter without in any way modifying its chemical nature, comparable to the magnetism of magnetic iron ore, which, like radioactivity, may be intensified, transferred, apparently destroyed and again called forth, and which, at the same time, also represents a mysterious manifestation of energy, without leading any one for a moment to imagine the existence of another element in magnetic ferroferric oxide not existing in the non-magnetic iron oxide. The idea of an elemental material difference was not thought of by any one, when Fr. Heusler succeeded in making magnetic alloys from unmagnetic metals such as manganese, tin, antimony and aluminum. Also in the case of radioactivity we should be free of material differences if the statement of F. Richarz and Rudolf Schenck should remain without valid objection, namely, that oxygen when ozonized becomes radioactive, so as to act upon the photographic plate, to make Sidot's blende (though only this kind of sphalerite) glow intensely and, like radium, to develop heat.

Considering the radium-craze now afflicting the world and affecting non-scientific circles especially, there is something humiliating to the chemist, after six years have elapsed since the discovery of radium, to say no more than that it resembles barium so closely that it can not be distinguished except by its higher atomic weight and its remarkable independent radiation. The chemical individuality of radium remains almost entirely unknown; nevertheless it is constantly sought, especially in those regions where pitchblende deposits occur, and where they already dream of developing radium ores and a future radium industry. So far as known, the occurrence of radioactive substances is tied to that of uranium. This is in the highest degree surprising and can not be understood if we are to assume the presence of special elements. Though the co-occurrence of certain elements is not uncommon and may be explained by their position in the system, their valence, the isomorphism of their compounds and other resemblances,

we nowhere meet such an exclusiveness as here would be brought to view. An exception might possibly be made as to the thorium, the radioactivity of which, according to G. F. Barker, is independent of its co-occurrence with uranium. However K. A. Hofmann and F. Zerban contradict this opinion, and F. Zerban believes that he has detected a small amount of uranium in the monazite-sand supposed entirely free from it. The method he used is not quite unobjectionable; it was originally devised (by Laube) for the working of uranium residues and not for analytical purposes.

The material thus far used for obtaining radium and other radioactive substances has mainly been the residue left by the K. K. Austrian Uran works after extracting uranium from pitchblende. This residue remains after pitchblende has been roasted, ignited with soda and niter, and extracted with water and dilute sulphuric acid. It consists mainly of gangue, silica, ferric oxide, basic iron sulphate and lead sulphate, but contains also some bismuth and silver. It amounts to 40 per cent. of the uranium ore worked, and we may estimate that in the 50 years of their existence the uranium works have dumped 150 to 200 tons of this residue. It is most difficult to estimate the total amount of radioactive substances in this dump, but the amount of radium will count only by grams, that of radiotellurium only by fractions of a gram.

The residue referred to possesses 4.5-fold the activity of metallic uranium. According to S. Curie, 1,000 kilos of the residue yielded 10 to 20 kilos crude sulfates of 30 to 60 activity, and these again 8 kilos of barium chloride containing radium also of 60 activity. This seems to prove that the radioactivity does not keep pace with the concentration of the barium compounds, but lags far behind. A reliable measure of the radium-amount is not furnished. Even a preparation of 3,500 activity must have consisted mainly of barium chloride, since it yielded 140 for the atomic weight which is only slightly in excess of that of barium. As to the activity of the purest radium chloride, we find no statements, but it is said that the best radium preparations have an activity of 50,000 to 100,000 times that of uranium.

Now arises the question: in what form of combination is radium contained in pitchblende, and in the final solution of the residue? In the latter it is certainly as sulphate, probably also in the former, since heavy spar is most commonly associated with pitchblende. Since now the solubility of the sulphates of the metals of the alkaline earths diminishes with the increase of the atomic weight, radium sulphate ought to be the most insoluble of all in this group. From this and from the isomorphism of barium and radium compounds, we must conclude that the heavy spar associated with pitchblende really must carry the radium of the Joachimsthal ores. But William Crookes has been un-

able to find any radioactivity in any of the heavy spars examined by him, and even if he did not specially examine heavy spar from Joachimsthal, the above result would be strange, since all other experience of the co-occurrence and mutual replacement of the elements would preclude that radium, in contradistinction to calcium and strontium, would be prevented from association with natural barium compounds, if it really were an element closely resembling barium. But if radioactive heavy spar occurs, its radium contents would pass into the barium chloride manufactured therefrom, and in that case it would not be difficult to separate it by fractional crystallizations on a large scale, however minute the radium contents might be. The experiment made by S. Curie with 50 kilos of commercial barium chloride has, however, given a negative result.

But even if radium for reasons at present unknown should exclusively follow the occurrence of uranium, it ought to occur in relatively wide diffusion at least in the Erzgebirge. For even outside of the deposits of pitchblende, such as those of Joachimsthal or of Johanngeorgenstadt, Schneeberg, Annaberg and Freiberg, one finds in the region specified frequently uranium-carrying rocks, especially granites, the uranium contents of which are indicated by an incrustation of calcium uranite acting on the sensitive plate and often visible in the crushed rocks used in the streets. It therefore appears not impossible to find in that region, where also bismuth is widely diffused, a new material which might successfully be worked for the extraction of radioactive substances. By producing radium in the pure state in larger quantities and by the thorough study of its chemical behavior we might possibly not only attain knowledge of the essence of radioactivity, but also place the existence of radioactive elements of individual character and definite chemical behavior beyond doubt.

EDUCATIONAL PROBLEMS.

By the Right Rev. the Lord Bishop of HEREFORD, D.D., LL. D.,
President of the Educational Science Section of the British Association.

WE hear much more than formerly about the public schools being the best training-place for good citizenship. Therefore, say the critics, it is reasonable to inquire how far their educational system, their ideals, their traditions, their fashions and the pervading spirit of their life fit the mass of their pupils intellectually and otherwise for the duties of citizenship and for grappling in the right spirit with the problems that will confront them. 'Any careful observer,' says one of these writers, himself a loyal public-school man, and intimately acquainted with school life, "any careful observer, who has studied the political moods and opinions of the middle classes in this country during the past few years, can hardly have failed to notice two obviously decisive influences: an ignorance of modern history and a want of imagination. For both of these defects the public schools must bear their full share of blame. It may be doubted whether any other nation teaches even its own history so little and so badly."

The result is that 'to the average public school and university man the foreign intelligence in his daily paper is of less interest than the county cricket; and though events of far-reaching importance may be happening almost under his eyes he is in the dark as to their significance.' "As regards the duties and aims of citizenship in all the various affairs of his own country, political, social, economic, he goes out from his school almost wholly uninstructed by the lessons of history, or by any study of the life and the needs of our own times. Again, as it is urged, the lack of imagination is hardly less dangerous to us than lack of instruction in the lessons of history and the social conditions and needs amongst which we have to live and work. No doubt the gift of imagination is a natural gift,—it can not be created. But, given the thing in the germ, it can be stimulated and developed, or starved, stunted, or even crushed out. No system of education that neglects it is even safe. For, without it, principle becomes bigotry and zeal persecution. It is conscientiousness divorced from imagination that produces Robespierres. Now, it is precisely here that we should expect the public schools to be most helpful, for it is through literature that the faculty is most obviously cultivated, and they all profess to give something of a literary training. But though the intention is excellent the performance is often terribly meager." What-

ever may be thought of such criticisms as these, which come from within our public-school life, it is, I imagine, generally agreed by those who know both our national needs and the work and influence of our public schools, that there is much room for improvement in regard to methods of teaching, the cultivation of intellectual interests and tastes, and the stimulating habits of thought in the majority of their pupils. In close connection with these considerations there are two questions of practical importance which deserve a prominent place in any study of our public-school education.

The first of these is whether it is good for all boys alike to continue their life at school, especially at a boarding school, up to the age of eighteen or nineteen; and the other is whether more encouragement and pains should not be given to developing the best type of day school, or, to put it somewhat differently, whether the barrack life of the boarding school has not, through fashionable drift and class prejudice, become too predominant a part of our English education at the expense of the home life with all its finer educational influences.

As regards the first of these questions, it will be remembered that Dr. Arnold considered it a matter of vital importance to expedite the growth of a boy from the childish age to that of a man. In other words, the boy should not be left to grow through the years of critical change from fourteen to nineteen without special regard to his growth in intellectual taste and moral purpose and thoughtfulness. His education during these critical years should be such as to rouse in him the higher ambitions of a responsible manhood.

Does, then, the actual life of a public school really conduce to this early development in the majority of cases? My own experience has led me to the conclusion that it can not be confidently held to do so. The boys in any of our public schools may be said to fall into two classes—those who in due course reach the sixth form, and during their progress through lower forms have an ambition to reach it; and, on the other hand, a numerous class who do not expect to rise to the sixth, don't care about it, and never exert themselves to reach it.

For the first class, I doubt if any more effective preparation for life has been devised than that of our best English schools; but the case of the second class is somewhat different. Many of these come to the end of their school time with their intellectual faculties and tastes and their sense of responsibility as men to a great extent undeveloped. From sixteen to eighteen or nineteen their thoughts, interests, and ambitions have been largely centered in their games and their out-of-school life, with the natural results that their strongest tastes in after life are for amusement and sport. Some of these boys, after loitering at school to the age of eighteen or nineteen, go to the university as passmen, some begin their preparation for the work of a doctor or a

solicitor, and many go straight from school into city life as men of business; and nearly all of them suffer from the lack of intellectual and moral stimulus during these later years of their school life.

Now many of these boys could without difficulty pass the entrance examination to the university at sixteen or seventeen, if well and carefully taught; and I have long held the view that such boys would greatly benefit by going to Oxford or Cambridge at the age of seventeen, or even sixteen, if suitable arrangements could be made. It was with this conviction in my mind that I published a scheme showing how this experiment might be tried about twenty years ago. The interval has confirmed me in the opinion that it would be a distinct gain to many boys to take advantage of such a scheme if made available. They would go out into the world from the university at the age of twenty far better equipped and prepared for life, both as regards knowledge and interests, tastes and character, than by going straight from school at nineteen.

And looking to my own University of Oxford, I see no reason why such younger students should not be safely received. There are at least three colleges in that university which would find it easy to adapt their arrangements so as to secure this. Each of these colleges has a hall in connection with it, well suited for the residence of a college tutor who might have special charge of these younger students, residing in the hall during their first year with somewhat stricter rules as to ordinary discipline and liberty, but in all other respects exactly on a par with the senior undergraduate members of the college.

On the subject of the day school, as compared with the boarding school, a subject which has not hitherto received the attention it deserves, I may venture to repeat here what in substance I have said on other occasions. Many parents are so situated that they have no choice in the matter; but to the educational inquirer it is a question of much interest and importance. The boarding school is admitted to excel in turning out strong, self-reliant, sociable, practical men of affairs, men who have learned by early experience not to think or make too much of small injustices, to rough it, if need be, with equanimity and cheerfulness, and to count it a man's part to endure hardness in a manly spirit. It is a fine type of character which is thus produced, at its best; but the best is not always seen in the result, and the system too often produces an undue deference to public opinion, a spirit of moral compromise and a loss of moral enthusiasm. The human soul in its finer parts is a very sensitive thing, and I do not think the barrack life of an average boarding school is always the most favorable for its healthy growth.

As I look back over the school days of my own pupils I feel that those of them had, on the whole, the best education who grew up as day

boys in good homes at Clifton College. There they enjoyed all the advantages of the cultivated home, which I need not here enumerate, and at the same time, through the arrangements we made for them, all the best elements in the life of a great boarding school. In the upper school of 500 boys, we had about 160 day boys living at easy distances from the school. These boys were divided into two houses—North Town and South Town—about eighty boys in each house, and they were treated for school purposes just as if they were living together in a boarding house. They were under the same rules as boarders in regard to hours of locking up, or the bounds beyond which they might not go without a note from their parents giving express leave. Their names were printed in a house list, a master was appointed as their tutor, whose duty it was to look to their educational needs and progress, to their reports and conduct, just as if they had been boarders and he their house master. Each house had its own room or library on the college premises, with books of reference, and so forth, for spare hours, and took its part with the boarding houses, and held its own in all school affairs, games and other competitions. And my experience of this system compared with others has led me to the conclusion that the form of education which may on the whole claim to be the best is that of a well-organized day school, in which it is clearly understood to be the duty of the masters to give their life to the boys in school and out of school, just as if they were at a boarding school, and in which the boys are distributed into houses for school purposes, just as if they were living in a boarding house. Under such a system they get the best of both worlds, home and school.

From the public school we pass naturally to the universities, and the first question that meets us is the influence they exercise on school education, through their requirements on admission or matriculation and the bestowal of their endowments and other prizes. On this part of my subject I have seen no reason to alter or modify what I said at Glasgow three years ago, and therefore I merely enumerate and emphasize the suggestions which I put forward on that occasion for the improvement of education both at school and college. I hold that it would be equivalent to pouring a new stream of intellectual influence through our secondary education if Oxford and Cambridge were to agree on some such requirements as the following:

1. In the matriculation examination (*a*) candidates to be free to offer some adequate equivalent in place of Greek. (*b*) An elementary knowledge of some branch of natural science, and of one modern language to be required of all candidates. (*c*) A knowledge of some period of English history and literature also to be required of every candidate, and ability to write English to be tested. (*d*) The examination in Latin and any other foreign language to include questions on

the subject-matter of any prepared books offered, some questions on history and literature, and translation of easy passages not previously prepared. (*e*) Marks of distinction should be given for work of superior merit in any branch of this examination, as, indeed, of every pass examination conducted by the university. Candidates should not be excluded from residence before passing this examination, nor should they be required to pass in all subjects at the same time; but the completion of this examination would be the necessary preliminary to entry for any other examination required for a degree.

2. On the question of endowments and the minimizing of waste in the administration of them there is much to be said, and I would suggest for consideration: (1) That, as a rule, open scholarships and exhibitions might be reduced to free tuition, free rooms and free dinners in hall, or thereabouts. (2) That every holder of an open scholarship or exhibition, whose circumstances were such that he needed augmentation, should, on application, receive such augmentation as the college authorities considered sufficient. (3) That care should be taken to discourage premature specialization at school.

For this end it should be required that no scholar should enjoy the emoluments of his scholarship until he had passed the matriculation examination described above; and a fair proportion of scholarships should be awarded for excellence in a combination of subjects. The universities might also do good service in the way of stimulating secondary education, if some small proportion of their entrance scholarships were distributed over the country as county scholarships, on condition that the county contributed an equal amount in every case. In this way some equivalent for the endowments, so cynically confiscated by the education act of 1902, might be recovered and used for the benefit of poor and meritorious students.

Other reforms, which would, as I believe, be productive of valuable results, are the requiring from every candidate for a degree a knowledge of some portion of our own literature and history, and the encouragement of intellectual interests and ambitions by abolishing all purely pass examinations. A pass examination, in which the candidates are invited simply to aim at a minimum of knowledge or attainment, is hardly worthy of a university. The opportunity of winning some mark of distinction in this or that portion of what is now a pass examination would frequently rouse some latent ambition in an idle man, and transform the whole spirit of his work. Thus a modest reform of this kind might be of practical benefit to the nation by helping in its degree to intellectualize the life of a great many of our young men, and draw out unsuspected interests, faculties and tastes.

My observations have run to such a length that I must, perforce, conclude, leaving untouched other aspects of university education and

training, whether in the old or the new universities, as also the whole subject of the higher education of women, and its proper relationship to traditional systems of instruction and study, framed and intended for men. And my last word is a word of practical inquiry. How is this section to be made of most value as an instrument of educational progress? I leave the answer to this question to those more competent to give it, merely putting on record my own feeling that it may do a valuable service and supply one of our special educational needs, if the working committee of the section, enlarged by the addition of various representative persons, makes it a duty to collect and publish year by year in succession a series of papers, the best that can be written by recognized authorities, on the chief branches of our English education, dwelling on its immediate and pressing needs, and how best to supply them. To do this the committee should set to work systematically, commencing in October with monthly meetings, and formulating, without delay, the scheme or series of papers to be prepared and presented to the next meeting of the association.

THE UNITED STATES PHARMACOPŒIA.

BY H. C. WOOD, M.D., LL.D.,

PRESIDENT OF THE UNITED STATES PHARMACOPŒIAL CONVENTION.

UNDERLYING our civilization, and often very necessary to our daily life, are agencies unrecognized by the general mass of humanity. Among these is a little book known as the 'United States Pharmacopœia.' It concerns most nearly the medical profession, but perhaps most vitally the general public. Probably four doctors out of five have no clear, correct conception of the Pharmacopœia, its intent and scope; whilst the ordinary citizen does not know of its existence. I have thought perhaps a short article concerning it might not be uninteresting to the readers of the THE POPULAR SCIENCE MONTHLY, and the concurrence of the editor in this belief has led to the present dictation.

The Pharmacopœia is an official standard list of drugs, in which is given so much of their natural history as may be necessary to enable the apothecary to judge of the genuineness and purity of an offered sample, and in which is also given a list of the proper preparations for use of these drugs, with the methods of the making of these preparations. The intent of the Pharmacopœia is to insure genuineness and purity, proper methods of preparing, and uniformity of strength in the preparations. A common, fallacious belief is that Pharmacopœial recognition means that the drug recognized is of value; the fact is that the United States and other Pharmacopœias have in them numerous drugs of very little use. The nature or *motif,* so to speak, of a pharmacopœia is not to distinguish between worthy and worthless drugs, but to see that a drug which is asked for is as sold by the apothecary pure, and that proper preparations of uniform strength are made by the apothecary.

The question which the framers of a pharmacopœia ask themselves, is not is this drug of value, but is there a demand for it by the profession of medicine? If five thousand doctors in the United States believed brick-dust to be a valuable remedy, and habitually used it, brick-dust would have to go into the pharmacopœia. Witch-hazel is probably as active and as useful as is brick-dust, but witch-hazel is a fad, and is enormously called for, and so witch-hazel must go into the pharmacopœia. The pharmacopœia exists for the purpose of requiring the apothecary to give in the first place pure brick-dust or pure witch-hazel when asked for; and in the second place uniform preparations of these remedies.

Every European country has its own pharmacopœia, prepared by

governmental officials; or, in the case of England, by a board especially authorized by the government. One of the peculiarities of Anglo-Saxon civilization is the performance by volunteer bodies under sanction of law of functions which are really governmental. Witness the Brethren of the Trinity, who control and manage the lighthouses of England; witness, also, the United States Pharmacopœial Convention, an incorporated society, which controls the United States Pharmacopœia. Little by little, now in customs regulations, now in pure food bills, now in this, now in that form, without any definite prearranged specific legislation, the United States Pharmacopœia has come to have the force of law in the United States. In the Latin countries the result of such a method would probably be bad; in the Anglo-Saxon lands with the habit of submission of the individual to the majority, the present method has been successful, and probably more successful than direct governmental rule would have been. The United States Pharmacopœia scientifically and practically ranks with any in the world, and obedience to its mandates in pharmacy and in medicine is universal.

The first attempt to make a pharmacopœia in the United States was in 1820; the result was not fortunate, but in 1830 a second edition was prepared which commanded the respect of the profession and was generally accepted. Before this period, if a doctor wrote for a tincture he would get it in one strength in Philadelphia, another strength in New York; or, perchance, the apothecary on the right side of Broadway would give him one strength of preparation, whilst his rival on the other side of the street would put up an entirely different article. What was formerly nationally true is now true internationally. A prescription written in New York for a certain much used poisonous remedy would be put up three times the desired strength in Montreal, where the British Pharmacopœia is in vogue. Arsenical preparations having the same name vary in strength from 1 in 10,000 to 2 per cent., according to the national standard in accordance with which they have been made. The growing freedom of intercourse among nations has made this situation intolerable, and various efforts have been put forth to correct the evil. At last the Belgian government, by summoning the International Conference for the Unification of the Formulas of Heroic Medicines, at Brussels, apparently solved the difficulty. In this conference, which was official and diplomatic in nature, each government of the civilized world was represented by a physician and a chemist or pharmacist and after much talk standards of strength were finally agreed upon for all very potent drugs, and pledges were made by most governments that the National Pharmacopœias should be made to conform. The new United States Pharmacopœia is on the eve of printing; the Committee of Revision has adopted the results of the Brussels conference, and it will be the first National Pharmacopœia of International scope.

THE MOSQUITO INVESTIGATION IN NEW JERSEY.

BY PROFESSOR JOHN B. SMITH, Sc.D.,

RUTGERS COLLEGE.

WHEN, a few years ago, it began to be generally realized that mosquitoes besides being sources of annoyance, were also dangerous to life and health because of their relation to certain diseases, the question of whether or not control or even practical extermination was feasible began to be seriously considered. Not until then was it realized how little was actually known of these pests and that, as a matter of fact, only a few species had been followed throughout their entire life cycle. It was assumed that all the species of the same genus had approximately the same life history, that the adults had practically identical habits, that what had proved successful in one locality would answer as well in all others, and that each locality with sufficient energy might secure exemption for itself.

The little book on 'Mosquitoes' by Dr. L. O. Howard, issued in 1901, summarizing what was then known, was published at the psychological moment and exerted an enormous influence. Mosquito brigades were formed, and improvement and other societies began work enthusiastically. New Jersey has always had something of a reputation in the mosquito line and at several points active work was begun. There were not wanting those that lacked faith, however, and there was abundant ridicule for those engaged in the work which, by the way, did not turn out as well as had been expected. We had now three classes in the state—the unbelievers and scoffers who were in the vast majority; the enthusiasts who believed firmly in local work, who formed a small but powerful minority, and a yet smaller class who thought that there might be a chance to get money out of it and who urged improvements that they might be engaged to carry out.

As the entomologist of the Agricultural Experiment Station, as well as in his capacity of state entomologist, the writer followed some of this early work, rather as a sceptic than otherwise; but after a season's observation found reason to believe that while eventual success in the direction of mosquito control could probably be obtained, the factors of the problem were not understood and that much work and money was being wasted or misapplied. The danger was that if failure resulted through ignorance the entire movement might be discredited and delayed.

Presenting the matter to Dr. E. B. Voorhees, the director of the station, he was authorized to ask the state legislature for a sum of money sufficient to make such a study of the problem as might be necessary to enable him to make practical recommendations, suited to conditions as they actually existed in New Jersey. Though at first inclined to treat the matter as a huge joke, the law-making body did pass the necessary act appropriating ten thousand dollars for the purpose declared, and this amount, it was intended, should cover two years of work; the minimum of time considered necessary. As a matter of fact it was spread over three years and the investigation is now completed. The detailed report is in the hands of the governor and will be printed in due course; but it may be interesting to summarize some of the conclusions for general information.

It is positively demonstrated that of the thirty-five species of mosquitoes occurring in New Jersey only a few are ever troublesome, and that not more than half a dozen need be considered from the practical standpoint. It has been further found that in this state the mosquito is not a local problem and that in many cases the pest that makes porches uninhabitable at night was bred miles away.

Beginning at the head of Newark Bay, the coast extending southward is edged with a fringe of salt marsh, broken only for a short stretch along Raritan Bay, and from Long Branch to Point Pleasant; and even here every stream has such an edging. Beginning at Bay Head there is an outer bar or strip of sand varying in width from half a mile to two miles or more, broken at irregular intervals but reaching to Cape May. On this narrow shore strip summer resorts like Seaside Park, Barnegat City, Beach Haven, Atlantic City, Ocean City and many others have developed and there is no better beach in the world for bathing and other aquatic sports. Between this outer fringe and the mainland is an area of low marsh, broken into islands by channels, with bodies of water, some large like Barnegat Bay and Great Bay, the majority small. Broad stretches of such marsh also extend along the large rivers of South Jersey so far as the tide makes the water distinctly brackish. Along the Delaware Bay shore the mainland extends closer to the water's edge and the salt marsh areas are smaller, and they gradually disappear along the banks of the river going north, as the water becomes fresh. Altogether there are many thousands of acres of such marsh and on it, in water ranging from fresh to salt, breed four species of mosquitoes. They breed there and nowhere else in the state; but practically two of these salt marsh forms dominate the country for from twenty to forty miles back. In other words they migrate in immense swarms from the places where they were developed and live for weeks or even months in places where, but for them, mosquitoes would be unknown.

The two troublesome species are *Culex sollicitans* and *C. cantator.* A third species, *C. tæniorhynchus* is also a migrant, but occurs in much smaller numbers and does not fly so far. The fourth, *C. salinarius* does not seem to migrate. Except the last, all these species lay their eggs singly in the marsh mud, not in water, and these eggs will maintain their vitality for months during the summer and remain unhatched during the winter. But when they become covered in summer by a spring tide or a heavy rain they hatch within an hour or two, and millions of wrigglers will be found on a marsh after a storm, where none were seen the day before. In a week these wrigglers are ready for the change to pupa and adult. After the adults have hatched, the first warm sultry night sends swarms numbering millions over the surrounding country. Few of these ever get back and none that leave the marsh finally ever reproduce their kind. In *C. sollicitans* only the females migrate and all those that were examined proved sterile; the migratory instinct replaces the desire to multiply. In *C. cantator* both sexes fly; but the males drop out after a few miles have been covered, and the females are sterile as a rule; a few exceptions have been found.

It might seem that having said so much, I had placed the problem of control beyond reasonable hope of practical solution: but the statements are yet incomplete and were left so to bring out forcibly the fact that it is no local matter: it is one with which the state must deal comprehensively. In truth not ten per cent. of that vast marsh area breeds mosquitoes at any time, and even a breeding area is not uniformly bad. The mosquito demands water free from fish or predatory insects of all kinds, that shall remain for at least a week. As a rule wherever tides go, the little species of *Fundulus* or 'killifish' will go and where they go no wrigglers can exist. Wherever fiddler crabs inhabit a marsh area, and there are thousands of acres so inhabited, their holes drain it completely and afford no chance to breed. It is usually at the edge of the highland, where the tide water works in through grass so dense that it bars fish and fills depressions, that the mosquitoes get their best chance and in a number of surveyed areas it was only the edge of the marsh that was reported dangerous. Other danger spots are the irregular, rather high marshes rarely covered by tides, which dry out completely at times, killing all aquatic life, and then fill all depressions by a heavy storm. Cat-tail marshes when they are at all dense are safe from mosquito breeding.

A very thorough survey of the entire salt marsh area determined that not over ten per cent. of it is at all dangerous, and the question arose, what can be done to make that portion safe. Of course any scheme that provided for the reclamation of the marshes and made them available for agricultural or other industrial purposes would also

eliminate mosquito breeding places; but that sort of reclamation is expensive and the total bill would be so great as to make it impossible to obtain consideration from any legislature. For the purpose of preventing mosquito development, reclamation is not necessary; it needs only such works as will enable all surface water to drain off completely in less than a week, or as will fill all depressions to a general level, whatever that general level may be.

The average marsh bottom is a tough clayey mud of variable depth, overlaid by a turf from six inches to a foot or more in thickness. This material is like a huge sponge from which the water will run out if it gets a chance, and which will absorb an enormous quantity of surface water. Its texture is also such that it will maintain even a narrow ditch perfectly and, if it is deep enough—two feet or more—no growth will start from the bottom. For slow drainage a ditch six inches wide, that will affect from thirty to fifty feet on each side can be cut by machine, and will dry off even the heaviest precipitation of rain in twenty-four hours. If a spring tide soaks the marsh the drainage is slower; but the surface will be free of shallow pools within forty-eight hours.

Lest it should be considered that this is all a statement of belief merely it should be said that in 1903 several bad areas near Newark and Elizabeth were experimentally ditched. When the work was begun the marshes were soft, full of holes, water-logged and hip boots were a necessity. The crop of salt hay could not be gathered until winter and lawn shoes for horses where they could be used at all, were a necessity. Throughout 1904 it was possible to walk over the drained area at all times, dry-shod except after heavy rains, and then twelve hours were enough to dispose of every pool or puddle. The crop of hay was heavier than for many years past, much of it was cut by machine and horses could be taken everywhere. Practically no mosquitoes developed on these areas.

The most convincing work however was done on the Shrewsbury River, extending from Seabright to North Long Branch and including nearly all the marsh area on both Monmouth Beach and Rumson neck sides of the stream. The territory had been roughly surveyed during the season of 1903 under the direction of local associations, and during the winter, at the request of these associations, one of the field agents and afterward an engineer was sent down to lay out a general drainage scheme. Before even the frost was out of the ground work was begun, and very soon afterward, in early March, wrigglers made their appearance in every pool and millions of potential mosquitoes were on the marsh. But the weather remained cold, larval growth was slow and the work was systematically pushed so as to reach the worst places first, the sods removed from the ditches being

used to fill the small deep holes that would naturally drain most slowly. Toward the end of the task in April, it became a race between the ditchers and the insects, which were beginning to pupate. The ditchers won and the last pool was drained before the first adult mosquito issued. It was interesting to watch a new ditch just opened into tide water, flowing in a steady stream toward the outlet and carrying a surface cargo of wrigglers and pupæ; and yet more interesting was it to see the 'killies' at the ditch mouth, taking care of every specimen that came out and gradually running up the ditch to meet them. On these hundreds of acres of meadow not one of the

MACHINE DITCHING ON THE NEWARK MEADOWS, SUMMER, 1904.

millions of mosquito larvæ came to maturity. On the marshes to the north and south where no work was done, the mosquito output was phenomenal and the early summer of 1904 will be long remembered. Not only the nearby cities and towns were sufferers, but the insects actually crossed both ridges of the Orange Mountains in their travels to the west, and swarmed in the hills about Paterson to the north. And in all this the Shrewsbury River country was practically free from mosquitoes and remained so all summer! There were some local fresh-water species that proved troublesome later in the season; but these were dealt with as fast as their breeding places were located. The marsh mosquitoes that had been the pest of previous years were conspicuous by their absence. A yet greater work was done by the City of Newark, where 3,500 acres of salt marsh were dealt with. No results were apparent in 1904, because the heavy early broods were allowed to develop unchecked; but the marsh is now dry except in a

very small section, and the spring of 1905 should tell an interesting story. There will be some mosquitoes, of course, because of the Elizabeth, Kearny and Jersey City marshes that are so near by. Elizabeth is showing an intelligent interest in the work and has estimates of the cost of clearing up her marsh land, which is not much less than the Newark area. The Kearny meadows at the junction of the Hackensack and Passaic are being filled by immense hydraulic dredges and will soon be not only mosquito free but industrially useful. At a number of other places in the state effective work has been done, and it is now all in the direction of permanent improvement. A

HAND DITCHING ON THE SHREWSBURY RIVER MARSHES, EARLY SPRING OF 1904

breeding place once eliminated makes a permanent reduction in the supply and is a positive gain.

By an amendment to the health laws passed during the session of 1904, waters in which mosquito larvæ breed are declared nuisances because of that fact alone, and the local boards of health are empowered to deal with them. In a number of places proceedings under this law have produced excellent results.

The investigations made are important as eliminating from consideration vast stretches of supposed breeding grounds like the cat-tail areas in the Hackensack Valley; as limiting the number of species which must be dealt with; as showing clearly the natural checks that may be practically utilized; as proving to demonstration that control amounting to practical extermination is not only possible, but not even difficult; and finally as furnishing a scientific basis for practical work.

THE PROGRESS OF SCIENCE.

THE PRESIDENCY OF THE CARNEGIE INSTITUTION.

Professor Robert Simpson Woodward, who holds the chair of mechanics and mathematical physics at Columbia University and is dean of the faculty of pure science, was elected president of the Carnegie Institution at the meeting of the trustees held at Washington on December 13. No selection could have been made more certain to meet the general approval of scientific men. They know that Professor Woodward possesses in an unusual degree the scientific eminence, executive ability, sound judgment and sympathetic personality which the position requires. His own researches have given him acquaintance with a wide range of the sciences, he having made contributions to mathematics, physics, geology and astronomy, while he has an intelligent interest in the biological sciences. He has been president and is now treasurer of the American Association for the Advancement of Science; he is a member of the National Academy of Sciences; he has been president of the American Mathematical Society and of the New York Academy of Sciences; he is one of the editors of *Science;* he has always done far more than his share to promote all efforts for the advancement of science.

The presidency of the Carnegie Institution is the most important scientific position in the world. There are attached to this office unusual opportunities and at the same time serious responsibilities. As our readers know, Mr. Andrew Carnegie gave three years ago preferred bonds of the United States Steel Corporation of the par value of $10,000,000 to establish at Washington an institution whose objects are defined in the articles of incorporation, as follows:

(*a*) To acquire, hold and convey real estate and other property necessary for the purposes of the Institution as herein stated, and to establish general and special funds;

(*b*) To conduct, endow and assist investigation in any department of science, literature or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies and individuals;

(*c*) To appoint committees of experts to direct special lines of research;

(*d*) To publish and distribute documents;

(*e*) To conduct lectures;

(*f*) To hold meetings;

(*g*) To acquire and maintain a library;

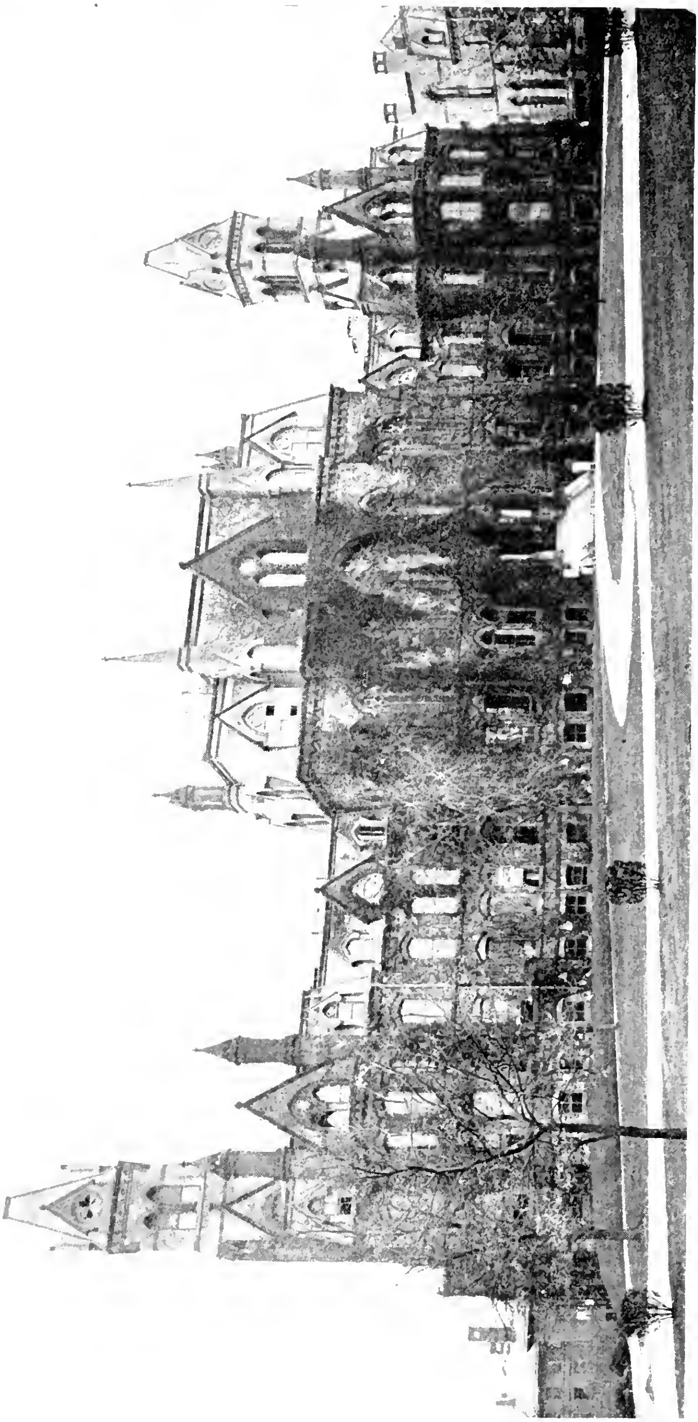
(*h*) And, in general, to do and perform all things necessary to promote the objects of said institution.

It is not remarkable and it is perhaps fortunate that three years have elapsed without committing the institution to any definite policy. Smithson's bequest 'to found at Washington an establishment for the increase and diffusion of knowledge among men' was in its objects closely parallel to Mr. Carnegie's foundation. The legacy of about $550,000 was received in 1838. All sorts of projects were embodied in bills, but the congress did not come to any agreement as to its uses until 1846. The delay in this case was certainly fortunate. Soon after the establishment of the Carnegie Institution a number of the leading American men of science took part in a discussion published in *Science* on its functions, which were summarized in the New York *Independent* in the following conflicting propositions:

1. Establish large and well-equipped laboratories at Washington for each science

2. Waste no money on buildings, but utilize existing laboratories wherever they may be.

3. Keep young men from deserting scientific pursuits by granting numerous fellowships to poor but worthy persons.



College Hall, University of Pennsylvania.

4. Give no fellowships, but, on the contrary, charge high tuition.

5. Give small sums to many individuals.

6. Money distributed in small amounts is wasted. Give at least $100,000 at a time.

7. Assist unknown and struggling men in small colleges.

8. Make no grants except to tried and proved investigators.

9. Grant only for specific purposes and on definite lines of work.

10. Give the investigator perfect freedom because he can not tell what he is going to discover beforehand, and would not be willing to publish his intentions.

11. Pay salaries of $10,000 a year to the leaders of each science

12. Expend no money on salaries, but supply only apparatus and books.

13. Publish a handsome series of quarto and folio memoirs.

14. Waste no money on big books and wide margins.

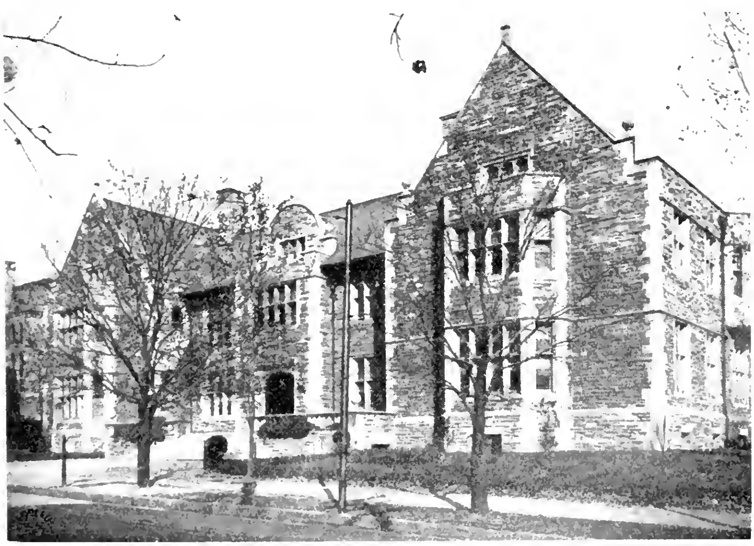
15. Grant degrees and award prizes.

16. Grant no degrees and offer no prizes.

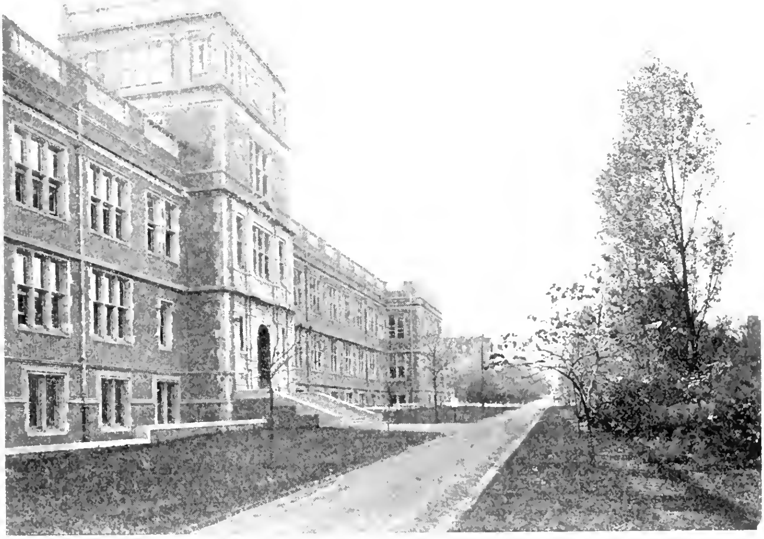
This represents in somewhat exaggerated form the diversity in the views of scientific men; and when there are such differences of opinion, it is wise to move slowly in adopting an irreversible policy. There are possibilities that appeal to the imagination in an institution that can play the part of a special providence throughout the country, scattering money just where it will bring forth fruit a hundredfold and discovering the struggling genius to give him the work he is best fitted to do. But there are difficulties and even dangers in such an undertaking. Under its new president the Carnegie Institution will be in a far better position than hitherto to carry out a policy of this kind. But it is probable that the institution will ultimately become one of the constituents of a great national university.

CONVOCATION WEEK AT THE UNIVERSITY OF PENNSYLVANIA.

The American Association for the Advancement of Science held its first meeting in Philadelphia in 1848. After an interval of thirty-six years it met for the second time in Philadelphia in 1884, when the attendance was 1,261. This was the largest meeting in the history of the association, but the numbers were increased by 303 members of the British Association, which met that year in Canada. At the Boston meeting of 1880 there were 997 and at the Montreal meeting of 1882 there were 937 members in at-



Houston Hall.



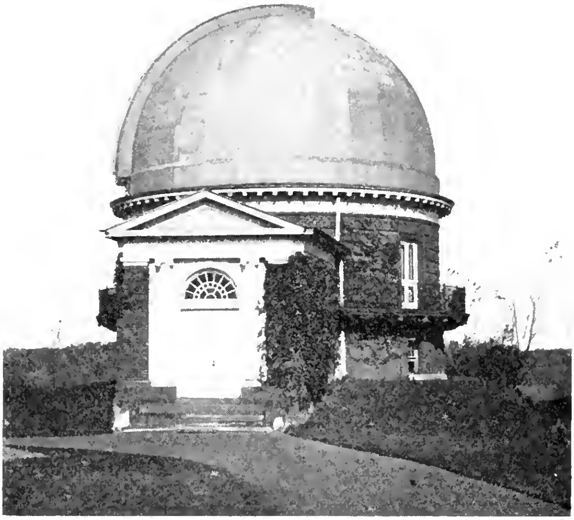
THE NEW MEDICAL LABORATORIES.

THE VIVARIUM AND BOTANICAL GARDEN.

tendance. These meetings represent a culminating point in the history of the association, and an important epoch in the development of science. Until 1882 there were only two sections of the association, one for the exact sciences and one for the natural sciences. But at about this period specialization and differentiation became imperative. The conditions were in part met by dividing the association into sections, but more adequately by the establishment of special societies. The American Society of Naturalists was organized in 1883, and has since held winter meetings, the membership being confined to professional students of the natural sciences. The American Chemical Society had been established in 1876; the Geological and Mathematical Societies were organized in 1888. Since that time special societies have been founded for all the leading sciences, and there is a tendency for them to divide into branches for the different sections of the country.

THE RANDEL MORGAN LABORATORY OF PHYSICS.

The establishment of these special societies represents an important advance, but its first effect was to weaken the parent association. Professional men of science found the amateur element too prominent in the summer meeting and the time was inconvenient for many of them. In spite of the great increase in the numbers of scientific men in the country, the meetings became smaller and the membership decreased. But this was only a temporary phase. The interests of men of science are not exactly limited by the conventional bounds of a single science. A zoologist, for example, may be interested in anatomy, physiology, pathology, paleontology, geography, botany, psychology, chemistry or some other science. It is also the case that those who attend the annual meetings like to see their friends from other parts of the country who may be working in fields remote from their own. It is advantageous consequently for the special societies to meet in groups at times,



THE FLOWER ASTRONOMICAL OBSERVATORY.

even though they may like occasionally to be isolated, and some machinery is necessary to make local arrangements, to secure reduced railway fares and the like.

Then while a small group of experts is the ideal condition for the presentation and discussion of special research, there are wider aspects of science and interrelations between the sciences for the adequate consideration of which workers in different departments must come together. There are also conditions of scientific progress, such as educational methods, scientific institutions, publication, government activities, etc., that need criticism and control. Neither trades unions nor corporations meet with universal approval at the present time, but it is obvious that some union among men of science is desirable for the support of their common interests, which in this case are fortunately identical with the interests of society. Lastly a federation of societies and a large gathering of scientific men is an important factor in keeping scientific work in touch with the outside world and in impressing on it the unity and weight of scientific research.

The complicated conditions appear to have been met by the establishment of 'convocation week' at the end of the Christmas holidays. Under the general auspices of the American Association arrangements are made at some large center for the meeting of the association and of the special societies that care to join with it. The special societies have complete control of their place and time of meeting, of their programs and membership; but without interfering with their autonomy the advantages of a great gathering of scientific men are assured. Thus at Philadelphia, beginning the day after Christmas, there will meet the American Association and its ten sections; the American Society of Naturalists, and some twenty special societies, including those devoted to astronomy, physics, chemistry, geology, botany, zoology, paleontology, bacteriology, physiology, anatomy, anthropology, psychology and philosophy.

The societies are fortunate in their

place of meeting this year. Philadelphia is centrally situated, at least for the Atlantic seaboard. The city is noted for its scientific societies and institutions. The University of Pennsylvania is one of the great universities which can offer admirable accommodations to all the societies and at the same time much to interest all men of science. Houston Hall, the beautiful club house of the students, will be an admirable center for social intercourse. The magnificent new medical laboratories will not only give excellent places of meeting for the societies devoted to the biological sciences, but a visit to them would repay a trip from Boston or even from Chicago. Each group of scientific men will find something to interest them in the advances made by the university during the ten years of Provost Harrison's administration. These include the laboratories of physics and of chemistry, the engineering hall, the observatory, the botanical garden, the vivarium and the museums, to mention only certain of the developments connected with the natural and exact sciences.

THE U. S. DEPARTMENT OF AGRICULTURE.

Much has been written of late about the work of the National Department of Agriculture, and widespread public interest aroused in its developments. There have been occasional criticisms of particular investigations, but there has been much to commend, which has appealed to people as having an important bearing in the development of agriculture. Interest in its annual report is by no means confined to the farmers and horticulturists, and no one can read it without being impressed by the fact that under the direction and stimulus of the present secretary of agriculture it has become an agency of great activity and aggressiveness in all that pertains to agricultural science and practise.

No reasonable expense or effort is evidently being spared to introduce or originate plants of improved quality, or better adapted to particular sections, to find remedies for diseases and pests of plants and animals, to extend the market for agricultural products, and to bring about an improved and more intelligent agriculture. In this the department is ably seconded by the agricultural experiment stations, located in every state and territory of the union, whose services the secretary acknowledges in the opening clause of his report and elsewhere. Many of the investigations reported from the department have originated and been worked out at the experiment stations, but they have been fostered and exploited by the department. Much of this work is a joint undertaking. The relations between these agencies are so close in object and method that specific reference to the stations is not made in each case, although evidently implied in a summary of what has been accomplished. The secretary endorses the movement for increasing the federal appropriation to the state stations, a bill for which is now pending in congress, and commends their work unsparingly.

Among the exigencies of the year which have called for special attention are the control of cattle scab and mange in the west, of which the individual states were unable to prevent the spread, and the serious and threatening ravages of the cotton-boll weevil in Texas and Louisiana. The latter work has been widely described in the press. The past season was a favorable one in bringing out the value of macaroni or durum wheats, introduced by the department in the semi-arid west a few years ago. It is estimated that fourteen million bushels were grown, and a great impetus was given to their culture. The growing of pedigreed sugar beet seed is showing home-grown seed to be equal to the imported seed, and often better. A

sweet orange of the hardy type, produced by crossing, is thought to give promise; and breeding and selection work is being carried on with tobacco to improve the leaf. Much-needed studies have been made upon the cold storage of fruit, to determine the conditions of growing, picking and handling for that purpose and for export. During the year over fourteen hundred kinds of seeds and plants were introduced, through agricultural explorers and correspondence, from various parts of the world. In this line special attention is being paid to the development of dry-land farming in the west. Evidence is presented of the value of copper sulphate for ridding water supply of obnoxious algæ, and progress is reported in the direction of making practically useful the important discoveries of Hellriegel, Wilfarth and others as to the assimilation of nitrogen from the air by plants with the aid of certain bacteria. An important new line of work is that relating to the breeding of animals, which has been undertaken on a systematic basis in co-operation with the experiment stations and with a special appropriation from congress.

In the investigations on human nutrition, the respiration calorimeter has been developed to a point of high scientific accuracy, and is being employed in studies on the comparative value of fat and carbohydrates as sources of energy to the body. Investigations have been completed on the much-agitated question of the value of the whole-wheat and graham flours as compared with ordinary flours, and dietary studies made at public institutions. Laboratories have been established for the inspection of imported food products, the character of which has greatly improved under this inspection; and investigations have been made of the effect upon health of food preservatives, such as borax. The irrigation investigations have had to do especially with the water requirements of crops, the economy of water, method of applying it, and pumping trials. Drainage investigations have been added, to include the large drainage problems growing out of the formation of marshes from irrigation, reclamation of the everglades of Florida, tidal marshes, etc.; and it is urged that this work in agricultural engineering be extended to include farm buildings and farm machinery, upon which there is much call for expert information.

The publications of the department, which reflect its activity and growth last year, reached the large number of 972 separate documents, the editions of which aggregated nearly twelve and a half million copies. Nearly half of these were 'farmers' bulletins' of popular character. A constantly increasing demand is noted for the department's publications by educational institutions, to be used for class work; and two thirds of the publications sold by the superintendent of documents were those of the Department of Agriculture. This attests the increasing appreciation of its work.

The generally optimistic character of the report indicates a commendable faith and enthusiasm in the work which the department is doing, and in the ability of science to solve many of the problems which now confront the agriculture of this country.

THOMAS MESSINGER DROWN.

By the untimely death of Thomas Messinger Drown, LL.D., on November 16, Lehigh University has lost a wise and beloved president, and American science a versatile and accomplished chemist, while a large circle of friends mourns the loss of a singularly winning personality, always cheerful, gentle, kindly and helpful. Dr. Drown was born on March 19, 1842, at Philadelphia. After graduating in medicine at the University of Pennsylvania, he pursued graduate studies in chemistry under

W. M. Flickinger, Photographer.

THOMAS MESSINGER DROWN.

leading American and German masters. For seven years he occupied the chair of analytical chemistry at Lafayette College, and for ten years a similar chair at the Massachusetts Institute of Technology. One of the founders of the American Institute of Mining Engineers, he served with conspicuous efficiency for ten years as its first secretary and editor of its *Transactions*, being later elected to honorary membership and in 1897 to its presidency. Dr. Drown did important original work in quantitative analysis in two directions. In metallurgy he devised methods which have become standard in the analysis of iron and steel. In sanitary chemistry he introduced improvements both in the methods and in the interpretation of water analysis. As chemist in charge of the investigation of the natural waters of Massachusetts, he instituted a series of investigations which resulted, among other things, in the unique map showing the distribution of 'normal chlorine' in the springs and wells of the entire state. Dr.

Drown was consulting chemist to the Massachusetts State Board of Health till the time of his death.

In 1895 Dr. Drown was called to the presidency of Lehigh University at a time when that institution's influence was at a low ebb. With rare courage and a faith in the institution, since justified by events, he restored to the university its own wavering faith and waning courage, gave it a good business administration, widened its educational horizons, and, by his sympathetic, intelligent guidance, fostered the steady, healthful growth characteristic of recent years.

During President Drown's administration the number of students has been increased from 325 to 650. The teaching staff has been proportionally increased and the grades of assistant professor and assistant, characteristic of modern university organization, have been introduced. Mineralogy and metallurgy have been divided into independent departments; likewise geology has been separated from mining, and electrical engineering from physics. A department of biology, inclusive of bacteriology, has been established, with adequate laboratory equipment, and a department of economics and history, intended equally for students in engineering and in arts. The department of philosophy and psychology, formerly an adjunct to the chaplaincy, has been given its independence, a psychological laboratory and courses in pedagogy being added. Hand in hand with President Drown's policy of expansion and differentiation went that of correlation. The School of General Literature has grown steadily by the side of the technical schools, which in turn have been increasingly hospitable to the introduction of liberal studies. Dr. Drown had long cherished a plan to evolve a six-year course fitted to furnish both a broad culture and an adequate training for the professional work of the engineer.

SCIENTIFIC ITEMS.

It is reported that Nobel prizes will be awarded to Sir William Ramsay in chemistry and to Lord Rayleigh in physics. — The Royal Society has awarded its Rumford medal to Dr. Ernest Rutherford, professor of physics at McGill University, for his researches on radio-activity.

Professor Charles A. Young, who celebrated his seventieth birthday on December 15, will retire from the chair of astronomy at Princeton University at the close of the present year and will become professor emeritus. —Dr. George H. Howison, professor of philosophy in the University of California, celebrated his seventieth birthday on November twenty-fifth, when he was presented with a *Festschrift* prepared by his former students.

During the recent excursion of the Eighth International Geographic Congress to the Grand Canyon of the Colorado in Arizona, a meeting was held in memory of Major J. W. Powell, in which his exploration of the canyon, his western surveys and his work as director of the United States Geological Survey and as organizer of the Bureau of Ethnology were briefly described. At the close of the meeting it was resolved to erect a monument in memory of Powell on the edge of the plateau overlooking the Grand Canyon.

THE POPULAR SCIENCE MONTHLY.

FEBRUARY, 1905.

AN ADDRESS ON ASTROPHYSICS.*

By Professor W. W. CAMPBELL,

DIRECTOR OF THE LICK OBSERVATORY, UNIVERSITY OF CALIFORNIA.

THE investigator in any field of knowledge must, as the price of success, both comprehend the general principles underlying his special problem, and give constant care to its details. Yet it is well, now and then, to leave details behind and consider the bearing of his work upon the science as a whole. Whether our subject is that of determining the accurate positions of the stars, or their radial velocities, the orbits of the planets, or the constitution of the sun, we are making but minor contributions to the solution of the two great problems which at present compose the science of astronomy. These problems, perhaps the most profound in the realm of matter, may be stated thus:

1. A determination of the structure of the sidereal universe; of the form of that portion of limitless space occupied by the universe; of the general arrangement of the sidereal units in space; and of their motions in accordance with the law of gravitation.

2. A determination of the constitution of the nebulæ, stars, planets and other celestial objects; of their physical conditions and relations to each other; of the history of their development, in accordance with the principles of sidereal evolution; and of what the future has in store for them.

The first problem has for its purpose to determine *where* the stars are and whither they are going. It has been ably treated under the head of astrometry.

The second seeks to determine the nature of the heavenly bodies —*what the stars really are.* This field of inquiry is well named, astrophysics.

* Delivered at the St. Louis International Congress of Arts and Science.

The motives of these problems are distinct and definite; but, judged by the ultimate bearing of his results, nearly every astronomer is working in both fields. The astrophysicist borrows the tools of the astronomer of position, the latter uses the results of the former, and *vice versa*. Let me give two illustrations. Astrophysics desires to know the relative radiating power of matter in different types of stars—the Sirian and solar types, for example. The meridian circle and the telescope discovered a companion to Sirius; the micrometer determined the form and position of the orbits; the heliometer observed the star's distance; and the photometer measured the quantity of light received from it. Computations determine from these data that Sirius is but two and one half times as massive as our sun, whereas it radiates twenty-one times as much light; from which it follows that a given quantity of matter in Sirius radiates many times as effectively as the same quantity of solar matter—a fact of prime importance in the astrophysical study of all Sirian stars. The parallaxes of the stars are needed by the student of stellar evolution as well as by the student of the structure of the heavens.

Again, the measurement of radial velocities of the stars has been left almost completely to those observers who are especially interested in astrophysical problems and methods, yet it is the student of astrometry who is eager to use their results. The overlapping of the two departments of astronomy is but the symbol of progress.

The term astrophysics is of the present generation, but the beginnings of astrophysical inquiry are somewhat older. Theories of planetary evolution by Kant and Laplace; observations of nebulæ and star clusters by the elder Herschel, and his wonderfully sagacious deductions concerning them; various studies of planetary markings and conditions; systematic investigations of the sun spots, including Schwabe's discovery of their eleven-year period—these constituted the main body of the science in 1859. But the spirit of inquiry as to the nature of the heavenly bodies was latent in many quarters; and Kirchhoff's immortal discovery of the fundamental principles of spectrum analysis opened a gateway which many were eager to enter. The spectroscope became at once, and has remained, the astrophysicist's principal instrument. However, the spectrum is not his only field, nor the spectroscope his only tool. Radiation in all its aspects, and the instruments for determining its quantity and quality, are the means to the ends in view. And the great generalizations of scientific truth, the doctrines of evolution and of the conservation of energy, for example, have been no less helpful here than elsewhere.

The study of our sun forms the principal basis of astrophysical research. The sun is an ordinary star, comparable in size and condition with millions of other stars, but it is the only one near enough

to show a disk. The point image of a distant star must be studied as an integrated whole; whereas the sun may be observed in considerable geometrical detail. We can not hope to understand the stars in general until we have first made a thorough study of our own star.

We are unable to study the body of the sun, except by indirect methods. The interior is invisible. The spherical body which we popularly speak of as the sun is hidden from view by the opaque photosphere. This photospheric veil, including the sun spots; the brilliant faculæ and flocculi, projecting upward from the photosphere; the reversing layer, in effect immediately overlying the photosphere; the chromosphere, a stratum associated with and overlying the reversing layer; the prominences, apparently ejected from the chromosphere; and the corona, extending outward from the sun in all directions to enormous distances; these superlatively interesting features of the sun constitute the only portions accessible for direct observation; and they are an insignificant part of its mass. They are literally the sun's outcasts. Our knowledge of the sun is based almost exclusively upon a study of these outcasts. Nevertheless, we are able to formulate a fairly simple and satisfactory theory of its constitution.

The materials composing the sun appear to be the same as those forming the earth's crust. Of the eighty known elements, slightly more than half have been observed in the reversing layer and chromosphere, by means of their spectra. The existence of others remains unproved, but there are no reasons to doubt that they too are present. Our most complete study of the sun's composition was made by Rowland, and he has said that if the earth were heated to the temperature of the sun, the terrestrial and solar spectra would be virtually identical.

The force of gravity at the sun's surface is well known, but the radial pressures at interior points are somewhat uncertain, as they depend upon the unknown law of increasing density with increasing depth. The minimum value of the pressure at the sun's center is thought to be fully ten thousand million times the pressure of our atmosphere at sea-level. The most probable value of the effective temperature of the sun's radiating surface is 6000° Centigrade, and the minimum value for the center is perhaps five million degrees. In view of these high temperatures, and the low average density of the sun, the interior must be largely gaseous, and perhaps entirely so; although, under the stupendous pressures, a great central core is probably of a viscous consistency, but ready to assume the usual properties of a gas when the convection currents carry the viscous masses up into regions of lower pressure.

The surface strata are radiating heat into surrounding space. To maintain the supply, it is imperative that convection currents should carry the cooled masses down into the interior, and bring corresponding hot masses up to the surface. These currents make the sun a very

tempestuous body. Further, the outrushing materials must acquire the higher rotational speeds of the surface strata, and the inrushing must lose their tangential momentum; and these can scarcely be ineffective factors in the sun's circulatory system.

The mechanical theory of the maintenance of at least a part of the sun's radiation must be considered as a necessary consequence of the law of gravitation—as unavoidably a consequence of that law as precession is. Helmholtz computed that a contraction of the solar diameter of less than 400 feet per year would suffice to maintain the present rate of flow. Whether this is the sole source of supply is uncertain, and very doubtful. The discovery of sub-atomic forces in uranium, thorium and radium is of interest in this connection. These radio-active substances have revealed the existence of intense forces within the atom, long dreamed of by students of physics and chemistry, but never before realized. The energy radiated by an atom of these substances is thousands of times greater than that represented by the ordinary chemical transformations of equal masses of any known element. Whether these forces are working within the sun, prolonging its life many fold, and incidentally diminishing the required rate of Helmholtzian contraction, we do not know; but we are not justified in treating gravitation as the sole regulator of radiation. We are encouraged to this view by the fact that the age of the earth, as interpreted by geology and biology, is many times greater than the superior limit set by the gravitational theory.

The dazzlingly brilliant photospheric veil which limits the depth of our solar view is due, with no room for doubt, to the condensation of those metallic vapors which, by radiation to cold space, have cooled below their critical temperatures. These clouds form and float in a great sea of uncondensed vapors, very much as do our terrestrial clouds; but it seems probable that the process of formation is continuous and rapid; and that they are added to from above, or from the interstices, and melt away from below.

The sun spots are the most extensively studied and the least understood of all solar phenomena. That they are large-scale interruptions in the photosphere, and at the same time the most striking evidence of atmospheric circulation, there can be no doubt. Observations made near the sun's limb, to determine whether the spots are elevations or depressions with reference to the photosphere, seem not to be reliable, perhaps because of abnormal refractions in the strata overlying and surrounding the spots. In the the earth's atmosphere, a high barometer is the indication of descending currents, which generate heat by compression and prevent cloud formation. Is not the umbra of a spot an area of high pressure, which forces the solar atmosphere slowly downward, preventing cloud formation in that area, but favoring the

growth of brilliant faculæ and flocculi in the regions of uprush surrounding the spot,—a theory first suggested by Secchi?

The visible spots are not the sole evidences of circulation. The surface is covered with a network of interstices, or vents between clouds, which probably exercise all the functions of the visible spots, but on a smaller scale.

There is no reason to question the truth of Young's discovery that the Fraunhofer lines originate in the absorption of a reversing layer—a thin stratum of uncondensed vapors lying immediately over and between the photospheric clouds.

The chromospheric stratum, several thousand miles in thickness, includes and extends far above the reversing layers, and contains the lighter gases, such as hydrogen and helium, and the vapors of calcium, sodium, magnesium and other elements which do not condense under existing temperatures.

The prominences have in general the same composition as the chromosphere. In some the lighter gases, and in others the heavier metallic vapors, predominate. They are portions of the chromosphere projected beyond its usual level by the more violent ascending currents, or perhaps by eruptions of a volcanic character; and these forces are almost certainly augmented by the pressure of the sun's radiation. It is difficult to account for the quiescent, cloud-like prominences in regions far above the chromosphere on any supposition other than that they are in equilibrium under the opposing influences of gravity and radiation pressure.

The nature of the forces which control the general and detailed coronal forms is but little understood. Motion within the corona has never been directly observed. Yet we can not question that the component particles are driven outward from the sun, and that many of them probably fall back into the sun, either singly or after combining to form larger masses. It is suggested that out-bound particles may be started on their way by the violent solar circulation, continued on their journey by radiation pressure, and arranged in the characteristic streamers under the influence of magnetic forces.

The light received from the corona is of three kinds:

1. A small quantity of bright-line radiations from a gas overlying the chromosphere. This gas is unknown to terrestrial chemistry, and astronomers provisionally call it coronium. It is distributed very irregularly over the solar sphere, and shows a decided preference for the sun-spot zone.

2. The bright-line radiations from coronium are almost a negligible quantity, in comparison with those from the same regions which form a strictly continuous spectrum, and which seem to be due to the incandescence of minute particles heated by the intense thermal radiations from the sun.

3. A small proportion of the inner, and a large proportion of the outer, coronal light are solar rays reflected and diffracted by the coronal particles.

Arrhenius has recently shown that Abbot's observation of an apparent temperature of the corona nearly equal to that of his observing room is in harmony with the spectrographic evidence of an inner corona composed of incandescent particles. Arrhenius finds that one minute dust particle to each 11 cubic meters of space in the coronal region observed by Abbot, raised to the temperature of 4620° absolute required by Stefan's law, would give a corona of the observed brightness, and of the observed temperature. The bolometric strip measured the resultant temperature of the few highly-heated particles and the cold background of space upon which the particles are seen in projection.

Arrhenius further estimates that a corona composed of incandescent dust particles need not have a total mass greater than 25,000,000 tons, to radiate the quantity of light yielded by the brightest corona observed. This is approximately that of a cube of granite only 200 meters on each side; a remarkably small mass for a volume whose linear dimensions are millions of kilometers.

This *résumé* of solar theory necessarily overlooks many unsettled points of great significance. Most important of all, perhaps, is that of the solar constant: does it vary, and in accordance with what law? Why is there a sun-spot period, and why are the large spots grouped within limited zones? Why does the form of the corona vary in a period equal in length to the spot period? Why does the angular speed of rotation increase from the poles to the equator? What is the origin of the faculæ and the flocculi? Why do the Fraunhofer lines show little evidence of high atmospheric pressure? Why are the radiations from calcium, one of the heavy elements, so prominent in the higher chromospheric strata and in the prominences? A great number of such questions are pressing for solution. Under the stimulus of the brilliant researches of our chairman, the reinventor and the leading developer of the spectroheliograph, cooperative plans for solar work on a large scale are now being organized. We should be vitally interested in promoting these plans; for the study of the sun, as the principal foundation of astrophysical research, has been unduly neglected.

The celestial bodies develop under conditions over which we have no control. We must observe the facts as they are, at long range, and interpret them in accordance with those principles of physical science which govern what seem to be closely related terrestrial phenomena. A successful study of the development of matter in distant space, under the influence of heat, pressure, electricity and other forces of nature

demands a complete understanding of the action of the same forces upon terrestrial matter. The astrophysicist dwells in the laboratory as well as in the observatory; and laboratory researches must supply the links which connect world life and star life.

It has not been possible for laboratory investigators to reproduce stellar phenomena on a scale approaching that occurring in nature, nor to duplicate conditions of temperature and pressure existing within the stars; and these are unfortunate limitations. Nevertheless, many successes have been achieved in this direction. The low-temperature triumphs of Dewar, Olczewski and others approximate to the conditions of space surrounding the stars. The electric arc and spark appear to reproduce the temperatures of many stellar chromospheres and reversing layers. The electric furnace of Moissan seems to supply temperatures comparable with those of the photosphere, and it promises to throw light upon the processes of cloud formation in the stars. Investigations as to the influence of varying pressures—from almost perfect vacua up to many atmospheres—as to the effects of varying electrical conditions and of other factors have answered many celestial questions, and introduced others equally pressing.

Laboratory observations have established that the spectra of the elements are not the same under all circumstances. We formerly thought it remarkable that nitrogen should have two or three characteristic spectra, or that a metal should have a spark spectrum and an arc spectrum. We are now confronted with the potent fact that an element may have a variety of spectra, depending upon the nature and the intensity of the forces employed in rendering it luminous. But for most cases these involve only moderate variations in the relative intensities of spectral lines. The complications which threaten to result therefrom are more apparent than real. The multiplicity of spectral reactions promises to be a powerful aid to analysis, by supplying a more exact key to the conditions in the celestial light source which produce the observed effects.

For many years following the application of the spectroscope to celestial problems it was supposed that a continuous spectrum must indicate incandescent solid or liquid matter. The situation is not so simple as this. Some gases radiating under high pressures give spectra apparently continuous.

The effect of increasing temperature conditions on certain spectra has long been well known. Certain lines are enhanced in relative brilliancy when we pass from the temperature of the arc to that of the high-tension spark, and *vice versa;* but it seems certain that, within measurable limits, the positions of the lines do not change under this influence.

Humphreys and Mohler have proved that the spectral lines are shifted by pressure;—toward the red with increasing pressure in the

atmosphere suronnding the arc. It is not difficult to see the bearing of this discovery upon astrophysical inquiry. Some subjects are made more complex; but the hope is held out that eventually we may detect these indications of pressure, differentially, in the brighter stars.

It is also known that the spectra of some elements are altered by the presence of other elements, but the extent and character of the induced changes are little understood. As the chemical elements are never found alone in celestial bodies, the serious consequences of this effect must be evident.

The temperature in glowing Plücker tubes is of great interest, from its bearing upon the probable temperatures of nebulæ, the auroræ and other bright-line phenomena of a diffuse nature. It is not certain that direct observation by any thermometric device can deal with the problem. The measures thus far attempted have assigned temperatures but a few degrees higher than that of the environment. These indications are probably correct for the average temperature of the contents of the tube, but hardly so for those molecules which are glowing. It has been suggested that perhaps a very small proportion of the molecules receive and carry the discharge; that while the molecules in action may be very hot, the average for all in the tube is very low. It seems reasonable to suppose, also, that the low-temperature indication is due to the fact that the current is actually passing but a small fraction of the time. The effect upon the eye is that of a continuous glow, whereas the thermometer measures the average effect.

The influence of a magnetic field upon the character of spectral lines, established in the laboratory by Zeeman, has not yet been observed in celestial spectra, but its detection may be merely a question of the dispersive power available on faint spectra.

It will be perceived that the interpretation of celestial spectra must be made with circumspection. We are not always justified in reaching conclusions upon the spectroscopic evidence alone; general conditions must also be taken into account. For example, shall we say that the temperature of the gaseous nebulæ is very high, because they have bright-line spectra? On the contrary, the difficulty of maintaining a high temperature in a mass so attenuated should be given at least equal weight. The radiating molecules or particles may for the instant be quite hot, but the effective temperature of the whole nebula is probably low.

The experimental verification of radiation pressure by Lebedew, and by Nichols and Hull, is far-reaching in its consequences. We must take this force into account, as truly and as constantly as we must consider gravitation. Radiation pressure requires us to reconstruct our theories of comets' tails, of the corona, of the zodiacal light, of

the auroræ,—in fact of every phenomenon of nature involving minute particles. And what celestial object does not involve them?

On the other hand, the student of the stars has pointed the way for the laboratory investigator, in many instances. The ultra-violet hydrogen series was photographed by Huggins, in the spectrum of Vega, before it was found in the laboratory; and Pickering has discovered another hydrogen series, in Zeta Puppis, which still awaits terrestrial duplication. The hypothetical element, helium, in the sun, waited a quarter-century for Ramsay's discovery, and the laboratory investigation of its more complete spectrum which followed. Students of the solar corona and of the gaseous nebulæ are discussing the properties of the hypothetical elements coronium and nebulium almost as familiarly as if they had actually handled them. Out of some 20,000 absorption lines mapped by Rowland, more than the half are awaiting laboratory identification.

In this connection, the mathematical relations existing between the positions of lines in the spectra of many of the principal elements, discovered by Balmer, Kayser, Runge and Paschen, have already been of great utility; and they can scarcely fail to illuminate the question of the construction of the atoms involved.

A new era of physical science was inaugurated about eight years ago by the discovery of argon on the one hand, and of the X-rays on the other. The former was followed by the discovery, in quick succession, of several other constituents of the earth's atmosphere which at present demand our attention as to their presence in chromospheric and auroral phenomena. It would be most surprising if the many forms of radiation, including those of the radio-active substances, discovered in the train of the X-rays, should not throw strong light upon the constitution of matter. And how shall we deal intelligently with the forms of matter in other worlds before we understand the constitution of matter upon the earth? The modern theory of electrons, in which material atoms play the subordinate part, and electric charges the principal part, promises to have a wide application to celestial phenomena. Further, the actual transport and interchange of matter in the form of small particles, from one star to another, as urged with great learning and skill by Arrhenius, seems to be a plain and unavoidable consequence of recently established physical facts. Should this theory stand the test of time, its far-reaching consequences would accord it a position of the first rank.

The photographic program inaugurated with the Crossley Reflector by Keeler comprised 104 negatives of the regions containing the principal nebulæ and star clusters. These photographs, covering but one six-hundredth part of the entire sky, record 850 nebulæ, of which 746 are new. If this proportion should hold good over the whole sphere, the

number discoverable with this instrument, with exposures of ordinary length, would be half a million. This estimate would be too large, in case the smaller nebulæ have a tendency to cluster around the prominent nebulæ, which to some extent is probably true. The number of stars visible in our great telescopes is of the order of one hundred millions. The dark or invisible bodies indicated by several considerations—the planets in the solar system, the spectroscopic binaries, the eclipsing variable stars, and the gravitational power of the universe—should outnumber the bright ones several fold. It is the thesis of astrophysics that all these objects—the nebulæ, the bright stars and the invisible bodies—are related products of a system of sidereal evolution. The general course of the evolutionary process, as applied to the principal classes of celestial objects, is already known. We are able to group these classes, with little chance of serious error, in the order of their effective ages.

The earliest form of material life known to us is that of the gaseous nebulæ. In accordance with the simplest of physical laws, a nebula must radiate its heat to surrounding space. In accordance with another law, equally simple, it must contract in volume—toward a center, or toward several nuclei—and generate additional heat in the process. Eventually a form of considerable regularity will result. Whether this form is that of a typical planetary nebula, of a spiral nebula, or of some other type, is a matter of detail. It is quite possible that nature uses several molds in shaping the contracting masses, according as they lie on one side or the other of critical conditions. The variety of existing forms is extensive. One can see very little resemblance in the Trifid Nebula, which is apparently breaking up into irregular masses; the Dumb Bell Nebula, from whose nearly circular form rings of matter seem to be separating; the great spiral nebulæ; the Ring Nebula in Lyra, with a central star; the compact planetary nebula G. C. 4390, containing a dense, well-defined nucleus; and many others of distinct types.

The condensed globular forms occupying the positions of nebular nuclei have almost reached the first stage of stellar life.

It is not difficult to select a long list of well-known stars which can not be far removed from nebular conditions. These are the stars containing both the Huggins and the Pickering series of bright hydrogen lines, the bright lines of helium, and a few others not yet identified. Gamma Argus and Zeta Puppis are of this class. Another is DM. + 30.°3639, which is actually surrounded with a spherical atmosphere of hydrogen, some five seconds of arc in diameter. A little further removed from the nebular state are the stars containing both bright and dark hydrogen lines;—caught, so to speak, in the act of changing from bright-line to dark-line stars. Gamma Cassiopeiae, Pleione and Mu Centauri are examples. Closely related

to the foregoing are the helium stars. Their absorption lines include the Huggins hydrogen series complete, a score or more of the conspicuous helium lines, frequently a few of the Pickering hydrogen series, and usually some inconspicuous metallic lines. Calcium absorption is absent, or scarcely noticeable. The white stars in Orion and the Pleiades are typical of this age.

The causes which produce bright lines in stars are not thoroughly understood; but atmospheres of higher temperatures than their underlying strata, or very extensive simple atmospheres, seem to be demanded. The former condition, on the large scale required, involves some difficulties, and mildly suggests the possibility that external influences may be acting upon the radiating strata of bright-line stars.

The assignment of the foregoing types to an early place in stellar life was first made upon the evidence of the spectroscope. The photographic discovery of nebulous masses in the regions of a large proportion of the bright-line and helium stars affords extremely strong confirmation of their youth. Who that has seen the nebulous background of Orion, or the remnants of nebulosity in which the individual stars of the Pleiades are immersed, can doubt that the stars in these groups are of recent formation?

With the lapse of time, stellar heat radiates into space; and, so far as the individual star is concerned, is lost. On the other hand, the force of gravity in the surface strata increases. The inevitable contraction in volume is accompanied by increasing average temperature. Changes in the spectrum are the necessary consequence. The second hydrogen series vanishes, the ordinary hydrogen absorption is intensified, the helium lines become indistinct, and calcium and iron absorptions begin to assert themselves. Vega and Sirius are conspicuous examples of this period. Increasing age gradually robs the hydrogen lines of their importance, the H and K lines broaden, the metallic lines develop, the bluish-white color fades in the direction of the yellow, and, after passing through types exemplified by many well-known stars, the solar stage is reached. The reversing layer in solar stars represents but four or five hydrogen absorption lines of moderate intensity; the calcium lines are commandingly prominent; and some 20,000 metallic lines are observable. The solar type seems to lie near the summit of stellar life. The average temperature of the mass must be nearly a maximum, for the low density indicates a constitution that is still gaseous.

Passing time brings a lowering of average temperature. The color passes from yellow to the red, in consequence of lower radiating temperatures and increasing general absorption by the atmosphere. The hydrogen lines become indistinct, metallic absorption remains prominent, and broad absorption bands are introduced. In one type, of which Alpha Herculis is an example, these bands are of unknown

origin; in another, illustrated by 19 Piscium, they have been definitely identified as of carbon origin. The relation between the two types is not clear. It has even been advocated that the evolutionary process divides shortly after passing the solar stage; that the reddish stars with absorption bands sharply terminated on the violet edges are on one branch, and that the very red stars with absorption bands sharply defined on the red edges are on the other branch. This plan of overcoming a difficulty seems to me to introduce a greater difficulty; and I do not doubt that systematic investigation will supply the connections now missing. That the denser edges of the bands in Type IV (Secchi) should occupy the same positions as the denser edges of absorption bands in Type III, can hardly be without significance; and Keeler's view that the carbon absorption bands in Type IV are matched by carbon radiation in some stars, at least, of Type III suggests a most promising line of investigation for powerful instruments.

There is scarcely room for doubt that these types of stars are approaching the last stages of stellar development. Surface temperatures have lowered to the point of permitting more complex chemical combinations than those in the sun. The development of 'sun spots' on a large scale is quite probable, and the first struggles to form a crust may be enacted. Type III includes the several hundred long-period variable stars of the Omicron Ceti class, whose spectra at maximum brilliancy show several bright lines of hydrogen and other elements. The hot gases and vapors seem to be alternately imprisoned and released. It is significant that the dull red stars are all very faint;—there are none brighter than the 5½ magnitude. Their effective radiating power is undoubtedly very low.

The period of development succeeding the red-star age of Type IV has illustrations near at hand, in the planets Jupiter and the earth; invisible save by borrowed light. When the interior heat of a body shall have become impotent, the future promises nothing save the slow leveling influence of its own gravitation and meteorological elements. It is true that a collision may occur to transform a dark body's energy of motion into heat, sufficient to convert it into a glowing nebula, and start it once more over the long path of evolution. This is a beautiful theory, but the facts of observation do not give it satisfactory support. There is little doubt that the principal novæ of recent years have been the results of collisions, either between two massive dark bodies, or between a massive body and an invisible nebula. The suddenness with which intense brilliancy is generated would seem to call for the former, but the latter is much more probable, in view of many facts. The nebular spectra of the novæ are generated in a few months; but in every case thus far observed the bright nebular bands grow faint very rapidly, and in the course of a few years leave a continuous spectrum,—apparently that of an ordinary star. Either the masses

involved in the phenomena are extremely small, or the disturbances are but skin-deep. In any case, the novæ afford little evidence as to the complete re-nebularization of dark bodies.

I spoke of the *average* temperature of a developing star as reaching a maximum near the solar stage, when the border-line between gaseous and liquid constitution is reached. This refers to the entire mass. The law of surface temperatures is quite a different one. The bright-line and helium stars seem to have hotter surfaces than the solar and red stars. The spectra which we observe are surface phenomena which indicate the temperatures of the radiating and absorbing strata. The maximum intensity of continuous radiations is higher up in the spectrum for the white stars than for the yellow and red, a safe indication of higher temperatures. The lines in white-star spectra are distinctly the enhanced lines thought to be produced by high temperatures. These facts are not inharmonious. Surface temperature is a function of the rapidity with which convection currents can carry heat from the interior to the surface. The comparatively low internal heat of white stars, delivered quickly at the surface by rapidly moving gases, may readily maintain higher atmospheric temperatures than the much hotter interiors of solar stars, whose circulation has the sluggishness of viscosity.

Sir William and Lady Huggins are inclined to assign greater importance to mass and density, as factors in evolution, than to temperatures. Their view is that under the influence of great surface gravity, the generation and radiation of heat is accelerated, and the life of the star is lived more rapidly. They have been led to this view, in part, by the apparent anomaly of double stars, in which the more massive primary is generally yellower than the less massive companion. The subject is one of great difficulty and importance, and, unfortunately, laboratory methods are on too small a scale of mass and pressure to solve the problem.

Up to the year 1800 only twelve variable stars were known. Chandler's catalogue dated 1888 contains 225 entries. The remarkable progress made by astronomical science in the past fifteen years is fairly indicated by the fact that in this interval the number of known variable stars increased from 225 to more than 1400. To Harvard College Observatory belongs the great credit of discovering nearly 900 of these objects.

In many respects variable stars constitute the most interesting class of objects in the heavens. The tens of millions of ordinary stars are undoubtedly growing older; and the tens of thousands of nebulæ, from which stars will eventually be formed by processes of condensation, are undergoing transformation; but appreciable changes in the ordinary stars and in the nebulæ proceed with extreme deliberation,

and no permanent changes have yet been noted. Variable stars, on the contrary, are changing before our eyes; and they repeat their fluctuations continually. They present opportunities for discoveries of the greatest interest in themselves, and of remarkable utility in the study of the problem of stellar evolution.

It is a conservative statement that in nineteen variable stars out of twenty we have little idea as to the causes of variability. The causes of the variations have been determined in the case of Algol and a few others of that class: large dark companions revolve around these stars, and once in every revolution the companions pass between us and the principal stars, thus preventing a portion of their light from reaching us. In Zeta Geminorum and three or four others of its class the spectroscope has shown that massive dark companions are close to, and rapidly revolving around, the principal stars. These invisible companions produce disturbances in the extensive atmospheres of the stars, and cause the observed variations in brightness; but the nature of the disturbances is still a matter of conjecture. Omicron Ceti and other stars of its class have given no evidence of companions. Brightness variations in them seem to be due to internal causes. Perhaps they have reached the age when solid crusts attempt to form on their surfaces, just as one day a crust struggled to form on the liquid earth. A crust formed one month may be melted or sink to a lower level a few months later. Perhaps there are 'sun-spots' on these stars, in scale vastly more extensive and in period shorter than those on our sun; but these suggested explanations may be far from the truth.

For more than half a century a great many astronomers have devoted themselves assiduously to making photometric observations of variable stars. There are a dozen observatories, both large and small, which are systematically devoting some of their resources to this work. By common consent of the profession, or by appointment from learned societies, there have for some fifty years been individual astronomers, or committees of astronomers, who systematize results, call attention to the need for observations of certain neglected objects, and in many other ways encourage the photometric study of variable stars. Photometers are inexpensive, the methods are simple, and results have rapidly accumulated.

Observations of variable stars with slit-spectrographs, on the contrary, are surprisingly meager and fragmentary. Not a single institution, not a single telescope, not a single observer, is working continuously or even extensively on the subject. Yet the method is a very powerful one: the few isolated studies made on variable stars have led to results of remarkable richness. The subject is one of great difficulty. Photographic spectra require much time for accurate measurement and reduction. And, finally, powerful and expensive instruments are demanded.

Harvard College Observatory has been remarkably successful in discovering variable stars by means of peculiarities in their spectra, as well as in classifying them, and in qualitative studies of many spectral details, using objective-prism spectrographs; but it is hoped that slit spectrographs, attached to powerful telescopes, may soon be devoted systematically to this subject, as it constitutes one of the richest fields now awaiting development.

A century and a half of meridian-circle observations has given to the world, as one of many priceless contributions, a knowledge of the proper motions of several thousand stars. Some of the ablest astronomers have used these results as a basis for determining the most probable elements of the sun's motion, and in studies upon the distribution of the stars in space. Unfortunately, these investigations necessarily involve assumptions as to the unknown distances of the stars.

A few years following the application of the spectroscope to the study of celestial objects, Huggins recognized that the Doppler-Fizeau principle supplied, in theory at least, the long hoped-for method of measuring the components of stellar motions in the line of sight—their radial velocities; and that the application of this method would enable us to determine both the direction and the speed of the solar motion, entirely independently of the distances of the stars. Efforts to apply this method met with signal failure for twenty years, and doubts even as to ultimate success were quite generally felt and freely expressed. The beginnings of success were made by Huggins and Pickering, in showing that photography reveals, with great clearness, the delicate spectral lines which the eye in purely visual observations is unable to see at all. In 1888, Vogel applied this knowledge in the first photographic attempt to measure radial velocities, and his work inaugurated a new era. His observations, obtained with a small telescope and imperfect spectrograph, were not sufficiently accurate to meet the needs of the principal sidereal problems, but they led to several brilliant discoveries at Potsdam, and were invaluable in marking out the path of progress. It was not until 1896 that the use of a powerful telescope, equipped with an efficient spectrograph, gave results accurate enough to satisfy present requirements. In fact, the accuracy obtained exceeded our most hopeful expectations.

It is not surprising that thirty years were required to develop successful methods. The work is so delicate that, unless suitable precautions are taken at every point in the process, the errors introduced may readily be larger than the quantities sought for. With the Mills spectrograph, for example, a speed of nine kilometers per second displaces the lines only 0.01 mm. The probable error of a velocity determination for the best stars, such as Polaris, is but one fourth of a kilometer per second, corresponding to a linear displacement of 0.0003

mm., or 0.00001 inch. In view of the newness of the subject, the richness of the field, and the fact that the more active great telescopes are now nearly all applied to this work, I append a list of the improvements which have contributed most powerfully to recent progress:

1. A realization of the fact that a spectrograph is an instrument complete in itself. The telescope to which it is attached serves only to collect the light and to deliver it properly upon the slit.

2. The development of a method of reduction which permits the use of all good stellar lines, irrespective of whether they correspond to, or lie between, the comparison lines.

3. The use of a longer collimator, permitting a wider slit, and requiring larger prisms, with greater resolving power.

4. The use of simple prisms, of better glass, with better optical surfaces.

5. Care in collimating, to insure that the star light and comparison light traverse identically the same part of the collimator lens.

6. The adoption of a compact and rigid form of spectrograph mounting, designed in accordance with good engineering practise.

7. The elimination of flexure effects by supporting the spectrograph, in connection with the telescope, in accordance with engineering principles. The conventional spectrograph had been supported entirely at its extreme upper end; the instrument projected out into space, unsupported, boldly inviting flexure under the varying component of gravity.

8. The use of a constant temperature case around the instrument.

9. Precautions taken to eliminate many sources of error from the measures of the spectrograms.

Up to December, 1900—the last month of the departing century—the speeds of 325 stars had been determined with the Mills Spectrograph in the northern two thirds of the sky. Omitting several stars whose lines could not be measured accurately, and some thirty spectrographic and visual binaries for whose centers of mass the velocities were still unknown, 280 stars remained available for deducing the relative motion of our solar system. The observational data were distributed symmetrically in right ascension, and the result for this coordinate of the apex agreed with Newcomb's proper-motion result within a small fraction of a minute of arc. The data were extremely unsymmetrical in declination, as there were few observations between — 15° and — 30° declination, and none whatever south of — 30°. The solution placed the apex 15° south of Newcomb's position. The deduced speed, 20 km. per second, is no doubt close to its true value.

There is a question whether the direction of the solar motion can be determined more accurately from proper motions or from radial velocities, an equal number of stars being available in the two cases; but as to the speed, no doubt of the very marked superiority of the spectrographic method can exist. This, however, is but incidental,

for the two methods are in fact mutually helpful and mutually dependent: the motion of every star involves both components.

In this connection two points call for appreciation: First, the motion of the solar system is a purely relative quantity. It refers to the group of stars used in the solution. We could easily select twenty or thirty of these stars whose velocities were such that the deduced motion would be reversed 180° from that given by the entire list of stars. We want to know the solar motion with reference to the entire sidereal system. A satisfactory solution of the problem demands that we use enough stars to be considered as representative of the whole system. Second, the great sidereal problems require that observational data for their solution should cover the whole sky. Until one year ago radial velocity measures were confined to the northern two thirds of the celestial sphere. Further attempts to deduce the solar motion from northern observation alone would not be justified. Observations in the southern third of the sky were needed, not only to represent that large region in the solution, but in order that the unknown systematic errors which affect the northern observations, as well as the southern, might be eliminated, through the symmetrical balancing of the material. Fortunately the energetic and wise policy of the Cape Observatory and the generosity of Mr. D. O. Mills have provided two complete equipments, which are now busily engaged in supplying the southern data required. The Mills spectrograph in the northern hemisphere has secured about three thousand spectrograms of approximately five hundred stars, and the Mills spectrograph in the southern hemisphere has secured four hundred spectrograms of one hundred and twenty-five stars. The number of stars not on the Mills list, and *accurately observed* with other high-dispersion spectrographs, is not known, but it is probably between one hundred and two hundred. We may reasonably expect that, in two or three years, as many as eight hundred well-determined radial velocities may be brought to bear upon pressing sidereal problems.

It is a frequent question: Is the solar system moving in a simple orbit, and will it eventually return to the part of its orbit where it is now? The idea of an affirmative answer to this question is very prevalent in the human mind. It is natural to think that we must be moving on a great curve, perhaps closed like an ellipse, or open like a parabola, the center of mass of the universe being at the curve's principal focus. The attraction which any individual star is exerting upon us is certainly very slight, owing to its enormous distance; and the combined attractions of all the stars may not be very much greater; for since we are somewhere near the center of our stellar system, the attractions of the stars in the various directions should nearly neutralize one another. Even though we may be following a definite curve at

the present time, there is, in my opinion, little doubt that we should be prevented from continuing upon it indefinitely. In the course of our travels we should be carried, sooner or later, quite close to some individual star whose attraction would be vastly more powerful than that of all the other stars combined. This would draw us from our present curve and cause us to follow a different one. At a later date, our travels would carry us into the sphere of attraction of some other great sun which would send us away in a still different direction. Thus our path should in time be made up of a succession of unrelated curves.

Spectroscopic binary systems, as by-products of radial velocity measurements, are of exceedingly great interest, from the light which they cast upon the construction of other systems than ours. When we look at the sky on a clear night, we may be sure that at least one star in six or seven is attended by an invisible companion, comparable in mass with the primary body, the two revolving around their common center in periods varying from two or three days in many cases, up to three or more years in others. For the triple system of Polaris the long period perhaps exceeds fifteen or twenty years. As the shortest-period visual binary now known, that of δ Equulei, is only 5.8 years, the gap between visual and spectroscopic binaries has been definitely closed.

The companions of binaries discovered by means of the spectrograph have not been observed visually in our powerful telescopes, although they have been carefully searched for. They may be so close to the principal star that, viewed from our distance, the two images can not be resolved. The separation of the components is probably less than one hundredth of a second of arc for most of the binaries thus far announced. Again, for very few of the systems are the spectra of both components recorded. This does not establish that the companion is a dark body, but only that it is at least one or two photographic magnitudes fainter than the primary. The fourth-magnitude companion of a second-magnitude star would scarcely be able to impress its lines upon the primary's spectrum. The invisible components in many spectroscopic binaries might be conspicuous stars, if they stood alone.

Only those systems have been detected whose periods are relatively short, and for which the variations of radial speed are considerable. The smallest observed variation is that of Polaris—six kilometers per second. Had the variation for Polaris been only one kilometer, it would no doubt have escaped detection. Such a variation could be measured by present instruments and methods; but this range would not have excited the observer's suspicion, and the discovery would have remained for the future. It is probable that there are more systems with variations of speed under six kilometers than there are with larger ones; and all such are awaiting discovery. The velocity of our sun through space varies slightly, because it is attended by com-

panions—very minute ones compared with the invisible bodies discovered in spectroscopic binaries. It is revolving around the center of mass of itself and its planets and their moons. Its orbit around this center is small, and the orbital speed very slight. The total range of speed is but three one hundredths of a kilometer per second. An observer favorably situated in another system, provided with instruments enabling him to measure speeds with absolute accuracy, could detect this variation, and in time say that our sun is attended by planets. At present, terrestrial observers have not the power to measure such minute variations. As the accuracy attainable improves with experience, the proportional number of spectroscopic binaries discovered will undoubtedly be enormously increased. In fact, the star which seems not to be attended by dark companions may be the rare exception. There is the further possibility that the stars attended by massive companions, rather than by small planets, are in a decided majority; suggesting, at least, that our solar system may prove to be an extreme type of system, rather than a common or average type.

Observations of stellar motions in the line of sight enable us to solve many other important auxiliary problems. Only one will be referred to here. The determination of stellar distances is exceedingly important, and correspondingly difficult. We know the fairly accurate distances of a dozen stars, and the roughly approximate distances of two or three dozen others. Radial velocity observations, in combination with proper motions, will enable us to determine the average distances of entire classes of stars. Let us consider the stars of the fifth magnitude, of which there are a thousand or more. They travel in practically all directions. A definite relation will exist between their average proper motion and their average radial motion, within a small limit of error. If meridian observations ascertain that the average annual proper motion of these fifth-magnitude stars is 0.03 seconds of arc, and spectrographic observations determine that their average speed in the line of sight is thirty-five kilometers per second, it is a simple matter to compute what their average distance must be in order to harmonize the two components.

A study of 280 observed stars as to the relation existing between visual magnitude and velocity in space led to interesting results. The average speed of 47 stars brighter than the third magnitude is 26 km.; of 112 stars between the third and fourth magnitude, 32 km.; and of 121 stars fainter than the fourth magnitude, 39 km. The progression in these results is very pronounced, and I think we are justified in drawing the important conclusion that, on the average, the faint stars of the system are moving more rapidly than the bright stars. This interesting indication should be confirmed or disproved by the use of a much greater number of stars.

The proper method of combining radial velocities for statistical

purposes is a question of great importance. The method of least-squares is based upon the assumption that the accidental errors of observation follow a certain law, found by experience to be substantially true. This method is not applicable to the combination of radial velocities, unless radial velocities are distributed in accordance with the law of accidental errors. Do stellar velocities whose values are near zero exist in greatest numbers? Or does some moderate speed predominate? The average speed *in space* of the 280 stars observed spectrographically is 34 km. When a much greater number of radial velocities is available, the law of distribution must be investigated, and a safe method of combination be developed.

Other practical questions exist as to the proper weights to assign to results of different degrees of accuracy, when it is desired to combine them statistically. The speeds of the brighter second- and third-type stars can be determined well within a kilometer per second, whereas the speeds of first-type stars, containing only broad and hazy lines, may be in error from five to fifteen kilometers. Again, low dispersion spectrography is developing so rapidly that in a few years the speeds of hundreds of the fainter stars will be known within two kilometers. Shall the weights assigned to individual results be proportional to the inverse squares of their probable errors? I think not. The deduced solar motion, for example, should refer to an observed program of stars which shall be representative of the entire sidereal system. It must refer to a star with hazy lines, or to a faint star, as truly as to a bright solar-type star. One poorly determined result for velocity, used alone, should have small weight, but a large number of such determinations should be given considerable weight; proper care being taken to avoid systematic error. Prudence would suggest that separate solutions be made, first for the stars whose spectra admit of accurate measurement, and later for those whose spectra contain hazy lines, or which have been observed with low dispersion. From these a guide as to the relative weights to be assigned to the three or more classes of stars in combination may be found.

Radial velocity observers are concerned as to the part played in the results by pressure in the reversing layers of the stars. The differential effects of pressure are too small to detect in stellar spectra by present means, and there is no known method of eliminating them. We have no recourse but to assume that the stellar lines, neglecting the effect of radial motion, are in identically the same position as the solar lines and the laboratory lines of the elements. Whether the lines in the blue stars are produced under lower pressure than those in the sun, and the lines in the red stars under greater pressure than those in the sun, remains unknown, but this is not impossible. The effect of systematic errors in observed speeds from this source, as well as from

other sources, would be eliminated from many statistical inquiries by having all parts of the sky represented in the solution.

Errors in the tables of absolute wave-lengths do not enter into radial-velocity results, provided the relative values are correct. In fact we scarcely need to know the wave-lengths at all, for the determinations of velocity may be put upon a strictly differential basis, and I incline strongly to the belief that this should be done. Let us consider the case very briefly. Rowland's wave-lengths are based upon spectrograms taken with high dispersion and resolving power. Radial-velocity spectrograms are secured with instruments of much lower power. Close solar and laboratory lines, of different intensities, clearly separated on Rowland's plates, are blended on stellar plates. For this and other reasons, the effective wave-lengths on the two classes of plates are different. The difficulty of assigning correct wave-lengths in the case of plates taken with a single-prism spectrograph is even greater: whole groups of separate lines are blended into one apparent line, and lines actually single are very few indeed. It is necessary to use blends, both in the stellar and comparison spectra. Two methods at least are available to eliminate errors in velocity due to errors in assumed wave-lengths. First: At the conclusion of a long series of observations of stars of the same spectral type, the velocity yielded by each line for each star should be tabulated. If one line gives velocities consistently large or consistently small, the conclusion is that its effective wave-length has been wrongly assumed, and we should be justified in changing it arbitrarily. And so on, for each line employed. This involves the assumption that the comparison bright-lines and the corresponding stellar lines have the same wave-lengths; and all the wave-lengths are reduced to one system, true for the particular spectrograph employed. The method is not entirely free from objection. Second: If the solar spectrum and the comparison spectra are photographed on one and the same plate, under precisely the usual observing conditions, measures of this plate, corrected for the observer's very slight radial velocity with reference to the sun, will form a reduction curve of zero velocity, expressed in terms of micrometer readings. If a spectrogram of star and comparison, made with the same instrument and measured in the same manner, is compared with this reduction curve, measure for measure, the speed of the star will be obtained directly, and irrespective of wave-length values; and many other fruitful sources of systematic error will be eliminated at the same time. Mr. R. H. Curtiss, of Mount Hamilton, formulated a method on this basis last year, and he has applied it to a specroscopic-binary variable star. The observations were made with a spectrograph whose dispersion is but one fifth, and whose exposure time for a given star is but one tenth that of the Mills spectrograph. The probable error for a faint star seems to be not more than twice as great as that for a

bright star with the Mills spectrograph. The method promises to be of great utility, capable of application to several thousand stars between the fifth and eighth magnitudes.

On account of the large proportion of spectroscopic binaries, stars should not be used statistically until observations covering several years have established the constancy of their motions. To determine the orbits and the speeds of the centers of mass of the binary systems, from twenty-five or more spectrograms each, is a task several fold more extensive than that of measuring the constant speeds of the non-binary stars.

There remains the question of cooperation, on the part of radial-velocity observers, to avoid useless duplication, and to increase the output of results. Seven leading observatories in the northern hemisphere, and one in the southern, are in this field, presumably with the intention of remaining indefinitely. A second observatory in the southern hemisphere, devoted exclusively to this work, is of an expeditionary character, and its long continuance is problematical. It is fair to the participating observatories to say, judging by results thus far published, that some are still in the period of experiment and development; and, in fact, that all observers are introducing frequent improvements, which lead to greater accuracy. As long as the development of instruments and methods is in rapid progress, formal cooperation is unwise. Premature cooperation leads to confusion. Duplication of observations for the principal stars is as valuable and desirable in radial-velocity measurements as in meridian determinations of stellar positions. But just as soon as the methods assume a reasonably stable form, the entire sky should be apportioned amongst the interested observatories, in accordance with carefully considered plans which shall permit and encourage individual initiative. I have little doubt that this point will be reached, by a sufficient number of observatories, within two years, and that it would be well to conclude the preliminary organization of cooperative plans within the coming year. Such plans should be formed with severe deliberation, as the labor involved would be commensurate with that devoted to the construction of the Astronomische Gesellschaft Zones for the entire sky.

The problems immediately confronting the astrophysicists of the twentieth century are serious ones. They call for our best efforts. The volume of work demanded is stupendous, and the difficulties to be overcome are correspondingly great. Nevertheless, the men and the means will be forthcoming. The mass of solid fact brought within the realm of knowledge by astronomers now living, many of whom are happily with us this week, is sufficient indication that the general solution of the problems of to-day is but a question of time. And we should be equally hopeful as to the problems of the future, for the desire to know the truth about the universe which surrounds us is an enduring element in human nature.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

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IN this age the knowledge of arithmetic is so widespread that it is difficult to conceive that it is comparatively young. The three R's, Reading, 'Riting and 'Rithmetic, seems to our mind almost axiomatic and fundamental in regard to education. It is, therefore, very interesting to read in histories of arithmetic that the earliest known book which contains a systematic exposition of the decimal system of numeration was written in the seventh century, and that our familiar arabic numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 can not be traced to an earlier century than the seventh. According to Ball's 'Short Account of the History of Mathematics,' the arabic arithmetic was practically unknown in Europe until the end of the thirteenth century. At that date numbers were written in Roman numerals. When we see a date inscribed in Roman numerals upon the portal of a public building, we witness the persistence, in art, of the system which was in universal use for all the arithmetical purposes of the civilized world only a few centuries ago.

How simple to our minds to-day seems such a numerical problem as a determination of the number of seconds in a mean solar day. We write down the factors as $24 \times 60 \times 60$, and in about twelve or fifteen seconds, with pencil and paper, we arrive at the answer 86,400. But how forbidding this problem would appear to us in the only form known to our medieval ancestors, namely, XXIV. times LX. times LX. How weary the way that would lead to the answer ! Is it any wonder that the counting machine, or abacus, was largely used for the simplest arithmetic; or that the expert arithmeticians in olden days were known under the title of 'sweating calculators'? We read that by the year 1400, the arabic numerals and simple arithmetic were generally known throughout Europe, and were used in most scientific and astronomical works. Most merchants continued, however, to keep their accounts in Roman numerals until about 1550. That is to say, unless history misinforms us, it took about a century and a half for the simple arithmetic of arabic numerals to permeate from scientific circles into the rank and file of the civilized nations. Looking backwards, this seems almost incredible. How was it possible for sensible people to shut their eyes to the simplicity of a scientific rational system of enumeration on the 1 2 3 . . . 8 9 0 plan, and adhere to the

laborious, unscientific, stupid system on the I., II., III. . . . VII., VIII., IX. plan? Nevertheless, sensible people long continued sturdily to resist the innovation. Moreover, it is stated that the change was frequently particularly resisted by the professional arithmetical experts.

The above presentations, while surprising at first apprehension, may claim perhaps a greater admiration and regard for our beautiful, and now universal, arabic arithmetic, which has asserted its supremacy by the laws of evolution and the long struggle for existence from which the fittest and the locally best emerge.

Even after our modern arabic arithmetical system prevailed, it was long before its decimal refinements were reached. According to Ball's history, decimal fractions were only invented about the year 1617, and it was not until the beginning of the eighteenth century that the decimal point came into use. In fact, an examination of eighteenth-century literature seems to indicate that fractions were more generally expressed as vulgar fractions in the earlier part of the eighteenth century, and it was not until the latter part that decimal fractions became customary.

A simple, practical and scientific system of units requires to be a decimal system, in order to transfer from a larger to a smaller denomination, or *vice versa,* by a mere change of the decimal point. This generally acknowledged fact is instanced by our American currency, which has three decimal units—the dollar, cent and mill. In effect, however, there is but one unit, the dollar; because a sum of money expressed in dollars is instantly converted into cents, or into mills, by a shift of the decimal point, without any appreciable mental effort. In Great Britain, however, the currency not being decimal, but divided into guineas, pounds, crowns, florins, shillings, pence and farthings, there are seven different units. Pencil and paper will generally be required by any but skilled mental arithmeticians to transfer a sum of money from one expression to another.

To an American, the superiority of the decimal currency over the non-decimal currency of his British cousin is generally so self-evident as to require no emphasis. But it is notorious that many intelligent and cultivated Englishmen do not recognize this superiority. They are so familiar by habit with their own currency, that they have forgotten their early schoolboy efforts in mastering it. Nevertheless, it is easily shown that the British system, as above enumerated, includes no less than 17 connecting ratios; namely, 1.05, 2, 2.5, 4, 4.2, 10, 10.5, 12, 20, 21, 24, 48, 60, 240, 252, 960, 1,008. The American decimal currency has only three connecting ratios, 10, 100 and 1,000; while these are effected without calculation, by merely shifting the decimal point.

The advantage of the decimal currency could not, however, have been realized before decimal arithmetic became generally known; or, say, prior to the eighteenth century.

What applies to currency units applies also to units of length, area, volume and weight. · A simple rational system of such measures must, as is generally admitted, be a decimal system. In this way large and small units may be related like the dollars, cents and mills of our currency. Such a system could not have been introduced until arithmetical science had reached a sufficiently general development, say, at the opening of the eighteenth century.

Commerce and labor must have demanded systems of weight and measures as far back as we have knowledge of the doings of nations. It is no wonder that these systems should have been crude, labor-absorbing and unscientific. No disparagement can be imputed to the English-speaking nations for inheriting from remote ancestry a crude system of weights and measures. Criticism of such nations can surely only be fairly laid at their doors when, seeing that their neighbors have a better modern system, up to date and practical, they remain supine and make no attempt to join the ranks of international progress.

In British and American measures of length we have the following units, all taught in the schools and all used more or less—league, statute mile, furlong, engineer's chain, surveyor's chain, rod-pole-or-perch, yard, foot, engineer's link, span, surveyor's link, hand, inch and line. These numerous units involve more than a hundred cross-connecting ratios, many of which would, it is true, be very seldom called for. Even, however, if we confine ourselves to mile, yard, foot and inch, we have the following six connecting ratios: 3, 12, 36, 1,760, 5,280, 63,360.

In the metric system there is the meter, about ten per cent. longer than the yard, and its decimal derivatives, all evaluated at a glance by a shift of the decimal point. In English speaking countries, roads are measured in miles and furlongs, short distances in yards, houses or ships in feet, horses in hands and small objects in inches. These expressions are not exchangeable or translatable without more or less mental effort. In the metric system, roads are measured in kilometers and hectometers, short distances in meters or dekameters, small objects in centimeters or millimeters and microscopic objects in micrometers or microns. Taking the length of a good-sized bacterium as one micron, it is immediately evident to the mind that a million such bacteria would fit into a meter, and one thousand million into a kilometer. If, however, we take the size of the bacterium as a certain small fraction of an inch, it takes time and considerable mental effort to find the corresponding relation of dimensions.

The same difficulty exists with units of area in the customary system. We have the square inch, square foot, square yard, square rod, rood, acre, square mile and township. All these units are used, although some are used only by surveyors. These involve 45 connect-

ing ratios, some of which are very complicated. In fact, many educated persons have a very imperfect conception of what constitutes an acre, and yet farms or estates are usually valuated and measured in acres. In the metric system, however, the square meter is the basis of all surface measurement and every expression in one unit is convertible into any other unit of the system, greater or smaller, by a shift of the decimal point.

The same comparison and contrast apply to volumes in the two systems. We have the cubic inch, cubic foot, cubic yard and cubic mile. International metric measure has the cubic meter and decimal derivatives. That is to say, there is virtually but one unit.

For the dry measure of volumes, we have, to make our confusion complete, pints, quarts, pecks, bushels, barrels, quarters and chaldrons. Moreover, our bushels, although nominally the same, actually vary according to the commodity measured; there being, according to 'The World Almanac,' some 20 different sorts of bushels by the laws of the United States, from a bushel of bran weighing 20 pounds avoirdupois, to a bushel of fine salt weighing 167. Add to this joy the recollection that there is a difference of about 8 per cent. between the British and American bushels, pecks, quarts, etc., and we attain the happy result that none can say precisely what quantity is meant by the term 'bushel' save by chance or context.

In regard to units of weight, or, more strictly, of mass, the metric system has the gram, which may be defined as the weight of a cubic centimeter of distilled water under specified conditions. Or, expressing the same relation in other words, a cubic meter of water weighs a metric ton of 1,000 kilograms and a cubic decimeter (called a liter) weighs one kilogram. Heavy weights are expressed in metric tons. lesser weights in kilograms, small weights in grams and tiny weights in milligrams. A mosquito will weigh in the neighborhood of a milligram, a U. S. nickel, fresh from the mint, five grams, an average man seventy kilograms, an average elephant about 3,000 kilograms or 3 metric tons. In this manner the weight of any object is brought immediately before the mind in relation to that of any other object, large or small, since virtually one and the same unit—the gram—is used throughout.

In contrast with this simple expression of weights in the metric system, we have in our systems three kinds of weights: viz., apothecary's weight, troy weight and avoirdupois. The two first mentioned have their ounces in common but differ otherwise. Although most substances are sold by avoirdupois weight, the precious metals sell by troy weight, and drugs in prescriptions usually sell by apothecary's weight. The ounce and pound weights kept by the druggists are for this reason generally different from the ounce and pound weights kept in the other

stores. It is impossible, therefore, to determine, except by context, precisely what is meant by the word 'pound' as a unit of weight in English-speaking countries. It may be the troy pound of 5,760 grains, or the avoirdupois pound of 7,000 grains.

By a felicitous arrangement, retained as a relic of the dark ages, pearls and diamonds are still weighed in a system of their own, the carat being 3.2 grains.

The cross-ratios connecting these various units are several hundred in number and very complex. Since, however, the ordinary citizen only deals with avoirdupois weight, in which there are nine units, the cross-ratios are 45 in number. Moreover, there are two tons in this country, a long ton of 2,240 pounds and a short ton of 2,000. In general literature, it is frequently impossible to determine which of these tons is referred to.

When liquid measure is considered, the medley and jumble of British measures is, if possible, worse. The British gallon is defined as 10 pounds avoirdupois of water at 62° F., the volume being 277.274 cubic inches. In the United States, the gallon is fortunate enough to contain 8.3389 pounds avoirdupois, or 58,372 grains, of water at a temperature of 39°.83 Fahrenheit. The U. S. gallon is thus about one sixth smaller than the British. The same happy ratio affects all the subdivisions of each system, viz., pints, quarts, etc. It is often difficult to tell whether English gallons or U. S. gallons are referred to, when the term is encountered in literature. Occasionally an American book will quote British gallons, or *vice versa,* without any reference to the discrepancy. Moreover, we have apothecary's fluid measure containing as units the minim, drachm, ounce and pint. These measures are again different in Great Britain and in the United States.

If we should attempt to collate all the British and American units of volume, both 'dry' and 'fluid,' and express each unit of the table in terms of all the others, the table would contain more than a thousand entries or cross-ratios. In the corresponding table of the metric system there would be virtually only one unit, and all others would be expressed therein by a shift of the decimal point.

If an attempt were made deliberately to construct a medley of weight and measures as a burlesque, for sensible practical people to make sport of, it may be questioned whether such a farcical hypothetical medley would be more illogical, incoherent or cumbersome than our own. Yet it would seem that ours is not worse than the old French, or German, or Austrian, systems that preceded the metric system in those countries, respectively.

It was stated in evidence before the committee on Coinage, Weights and Measures of the House of Representatives in Washington, two years ago, by an expert in education, that about two thirds of a year

of labor in school could be saved to the scholars of all the U. S. public schools, by the substitution of the metric system for the existing system. This saving would enable the scholars to learn more in other directions during the time saved. Nevertheless, it is sometimes gravely asserted that the value of the present system is the difficulty it provides for exchange, and estimates, and computations of all kinds, thus affording useful mental exercise, both for school children and for adults. Fears are occasionally expressed that the substitution of the metric system would make mental arithmetic in such matters so easy that the aptitude would be lost. According to this argument, we should make all mental operations as hard as possible, artificially.

So complex is our customary system of weights and measures, that there are comparatively few persons who can recite from memory all the various tables taught in our schools. So ambiguous is the system, that many cultured persons are not aware of the difference between British and U. S. gallons, quarts, pints, bushels, pecks, etc. Some cultured persons are even unaware of the difference between the apothecary's ounce or pound and the avoirdupois ounce or pound.

The argument is often made that the English-speaking people should adhere, for patriotic reasons, to their national standards as against standards of French creation. Surely the answer to such a plea is that the question is not between the English and the French peoples, but between the English-speaking peoples and the rest of the civilized world. The metric system is the only system of weights and measures that can be called international. Moreover, only the very best available system should be good enough for Americans.

It is sometimes complained that the meter as a unit should be set aside because it is inaccurate. In order to make the standard length international, France decided upon a decimal fraction (the ten millionth part) of the distance between the geographical pole and the equator, measured on the Paris Meridian of the earth's surface. The meter arrived at by the French geodesists at the beginning of the nineteenth century appears by the most recent publications of the Bureau des Longitudes to have been a little short of the mark. It seems that the international meter, defined as the distance between the centers of two marks on the standard meter bar kept in the International Bureau of Weights and Measures at Paris, is just about one-fiftieth part of 1 per cent. shorter than the ten millionth part of the quadrantal arc of the earth above referred to. This small discrepancy is evidently of no material consequence; partly because a discrepancy ceases to be a source of error as soon as its magnitude becomes known, and partly because all copies of the meter are made by bar-to-bar comparison and not from comparison with the dimension of the earth,

which dimension is stated to differ appreciably from meridian to meridian, owing to irregularity of form.

Another objection often made to the metric system is the loss of binary subdivision. In the system of binary subdivision we have halves, quarters, eighths, sixteenths, thirty-seconds and sixty-fourths, etc. It is contended that in decimal division these subdivisions become awkward beyond halves; viz., 0.5, 0.25, 0.125, 0.0625, 0.03125, 0.015625, etc. This is, no doubt, a weak point in the decimal system generally. If the base of our notation were 12, or 16, instead of 10, the objection would be made more remote. But it is useless at this epoch to discuss an international change of arithmetical notation. There does not seem to be the least prospect of such a change, nor the least hope of its being made in the near future. Moreover, the same objection applies to our decimal currency, and is scarcely felt in that direction. Brokers reckon in the binary scale to one eighth, but are said not to employ sixteenths. An inch is often subdivided to sixteenths, but thirty-seconds are seldom used, sixty-fourths very rarely, and yet smaller binary subdivisions are almost unknown. In fact, where fine micrometer measurements are made in inch measure, they are nearly always in decimals of an inch, and not in binary subdivisions. In metric countries, the decimal subdivisions do not seem to constitute a noticeable hardship.

Most persons grant that the metric system is superior for practical as well as scientific purposes to the British system, but dread the cost of a change or transition. There can be no doubt that the question of expense of transition is a serious one. In fact, if the only alternatives were the immediate compulsory adoption of the metric system on the one hand, to the extent of throwing away every existing measure and standard, or never adopting the metric system, on the other hand, it is probable that the latter alternative would be necessary; for the trouble, vexation, expense and litigation to be expected from immediate change would be terrible to contemplate. Fortunately, no such alternatives are presented. We have the history of almost all the continental nations of Europe to guide us in estimating the degree of difficulty which would be expected in effecting the change.

In France, the native land of the metric system, and the first country officially to adopt it, the change was made very slowly. During the first half of the nineteenth century France stood almost alone in this reform. Moreover, the initiation of the reform in 1795 took place in the year III. of the French Republic, and was doubtless greatly aided by the general upheaval of long established customs and traditions in France about that time. If it had not been for the French Revolution, so terrible in many of its aspects, the metric system might never have become a practical reality.

In the latter half of the nineteenth century the reform spread over continental Europe. Spain officially adopted the system in 1849, Italy in about 1850, Portugal in 1852, Switzerland virtually in 1851, through the medium of a transition system, and, finally, in 1877, when the complete system was officially adopted. Germany and Austria-Hungary officially adopted the system in 1871. Russia, semi-officially, in 1900. Denmark alone in continental Europe has declined to make the change; but even there, it is said that the system is much used, owing to the influence of neighboring countries, in spite of the government attitude.

The pressure upon the continental European nations to adopt a uniform international system has doubtless been considerable, owing to their relatively close geographical association. Beyond the advantages inherent to the system and its international use, there does not seem to have been any pressure which would have brought about the change. Few persons now living in Spain or in Italy would be able to remember the conditions at the time of inaugurating the metric system. In Germany, however, the official change was made by law only about thirty years ago, and the events connected with the change are remembered by a large section of the people. The testimony seems to be that the change was virtually made in the cities during the course of a few weeks, and in the country districts during the course of a few months; so that in a year the metric system was practically universal. The manufacturers continued to use their tools, standards and machines just as in the past; except that they gradually measured their products in the new units; and as time went on, and machines became renewed, the machines were changed in such a manner as to produce even metric sizes.

So far as can be ascertained from the history of transition to the metric system abroad, the transition in this country should not require any machine, tool or piece of apparatus to be discarded or abandoned. The difficulty of transition would not be in expensive new machinery. It would lie in translating the old familiar sizes made by existing machinery into the new units. The trouble would be intellectual rather than material. New price-lists would have to be prepared in terms of the new units. In stores where sales had been previously made by the yard, they would be made, in the new regime, by the meter, which is a measure about ten per cent. longer. In stores where sales had been made by the pound, the new sales would be by the kilogram, which is somewhat more than two pounds (about 2.2). This would involve a change of foot-rules, yard-measures, and sets of scale-weights, together with a change of price-lists. If the change occurred suddenly, there would be great confusion; but if it took place gradually, the trouble would probably not be serious. To

a person accustomed to buy sugar at six cents a pound, it would be a little perplexing at first to buy it at 13 cents the kilo, or 6½ cents the half-kilo. It is the experience of the average American, however, that in a foreign city, where the metric units and coinage have both to be acquired, familiarity is obtained after about two weeks. Consequently, less time should be needed to gain familiarity with the metric system, when the coinage is unchanged.

If it be questioned as to whether it is worth while for the whole nation to be involved in this trouble and expense of transition, it should be remembered that practically all countries, except the English-speaking countries, have already considered it worth while to make the change, and that none of these countries has expressed regret for the step. Moreover, the labor involved in the change, if the transition is not too sudden, will be small compared with the labor saved to the young in acquiring the present complex system, as well as to adults in wastefully consuming time for constantly applying it.

The United States cover so large a territory, and have within this territory so large a market, that the pressure upon their citizens for meeting the requirements of trade with countries outside of Great Britain, or her colonies, has not been felt as it has been felt in countries like Germany. Nevertheless it is the often-repeated statement of the U. S. consuls living abroad that the non-metric price-list, weights and measures of American manufacturers are a handicap on American trade with metric countries.

Already the metric system is used in the United States for nearly all scientific work and literature. It has even permeated popular literature to some slight extent. It has already invaded pharmacy and microscopy. The international electric units are metric units. It has come into our currency. A nickel weighs, by law, five grams, and a dollar twenty-five. The U. S. foot is defined by law as a certain fraction of the international meter.

The colonies of Great Britain, less conservative than their mother country, have recently urged Great Britain to adopt the metric system. In August, 1902, the prime ministers of the colonies officially urged upon the Secretary of State the importance of adopting the metric system throughout the British Empire. At the Congress of the Chambers of Commerce of the British Empire, held in Montreal in August 1903, with delegates from all parts of the empire, a strong resolution was adopted concurring with this action of the colonial prime ministers, and urging the British government to adopt the metric system.

The parliament of Australia passed a strong resolution in favor of adopting the metric system throughout the British Empire, in June. 1903. A similar, but less decided, motion was carried in the Cape of

Good Hope House of Assembly in August, 1903. A similar action was taken about the same time in the New Zealand parliament.

A bill for the compulsory adoption of the metric system in Great Britain within a specified period, passed the House of Lords last year, and has also passed its first reading in the House of Commons. The bill was supported by petitions from councils of cities, towns and counties, having a total population of 2,800,000; as well as by trade-unions and other organizations to the total enrolment of one third of a million persons.

In this country, a bill for the compulsory adoption of the metric system within a specified time was introduced into congress in 1903, but was withdrawn. Resolutions in favor of the adoption of the metric system in the United States have been passed by the Franklin Institute, the American Institute of Electrical Engineers, and the American Electrochemical Society. On the other hand, resolutions opposing the adoption of the metric system have been recently passed by the American Society of Mechanical Engineers, the American Association of Toolmakers, and the Association of American Manufacturers. The principal objection in these cases seems to have been the dread of expense in transition.

It would seem to be only a question of time when the elimination of the useless, and the survival of the fittest, will bring about the universal adoption of the system. Even assuming, however, that the change were made officially by the United States government within the next ten years, the existing units would continue to persist in some degree for many years. Thus inch-pipes will doubtless exist in the country for many years to come as a physical reality; even though such pipe should come to be called 25-millimeter pipe. Even at this time, more than one hundred years after the inauguration of our decimal currency, one still occasionally hears the 'shilling' quoted as a price, a relic of colonial currency. When so used in New England, a 'shilling' appears to mean one sixth of a dollar, or 16 2-3 cents.

In time to come, and probably much beyond the date of the universal adoption of the metric system, decimal reform may perhaps extend to other fields. Thus the cumbersome and complex systems of dividing angles sexagesimally into degrees, minutes and seconds, is generally admitted to be much inferior to a decimal subdivision. Some day, perhaps, angles may be expressed decimally all over the world. The day also is divided in a cumbersome way into hours, minutes and seconds. A decimal subdivision of a day would have much advantage over the existing plan. But decimal reform in angles and in time is undoubtedly much more remote and problematical than in weights and measures; nor is there the same exigency for decimal reform in these directions.

A BOTANICAL LABORATORY IN THE DESERT.

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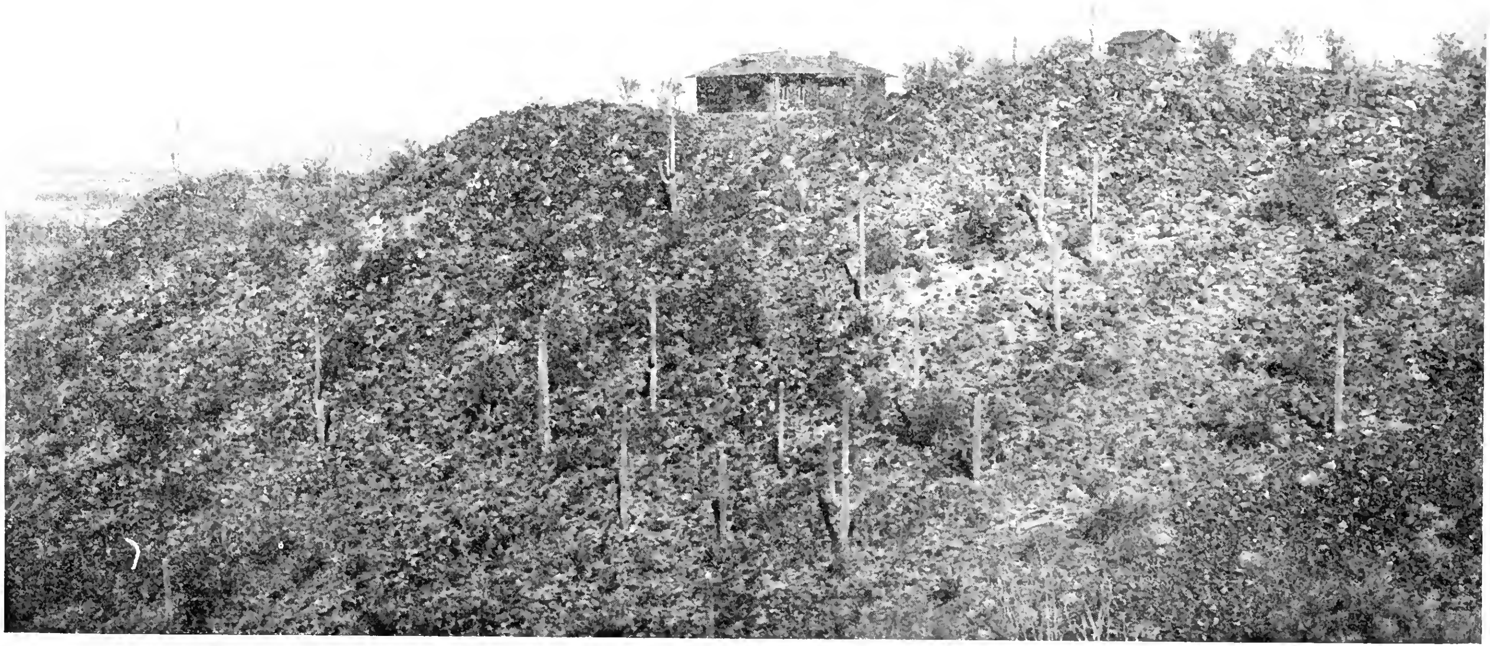
TWO years ago the Carnegie Institution determined to establish a laboratory to be devoted to the special study of desert vegetation. The plan originated with Mr. Frederick V. Coville, who, under the auspices of the Smithsonian Institution, had for some dozen years previously been a close student of the plants of the southwestern American desert. His interest was fixed by his experiences as a member of the memorable Death Valley Expedition of 1891. After Mr. Coville's plan had been adopted by the Carnegie Institution, an advisory board, consisting of Mr. Coville and Dr. D. T. MacDougal, was appointed. The first work of this board was the choice of a proper site—a task which will be conceded to be neither easy nor unimportant when the great extent and variety of the North American Desert is appreciated. Both of these gentlemen were, however, possessed of wide personal knowledge and experience of this region and brought to the solution of the problem ripe judgment. After a further personal examination of all of the most promising areas, including the deserts of Texas, northern Chihuahua and Sonora in Mexico, New Mexico, Arizona and of California, the choice rested upon Tucson, in southern Arizona. The results of this investigation are embodied in an extensive report* which is full of valuable data and most instructive and beautiful illustrations. The wisdom of the choice of the advisory board may very naturally be questioned, and I confess to have entertained some doubt in this regard. After a personal examination, however, of nearly all the above mentioned regions, and after spending the major portion of the past summer at the Desert Botanical Laboratory, I am now of the opinion that the action was well-advised and is fully justified. I am therefore taking occasion at this time to give an account of the laboratory and its surroundings from my own point of view.

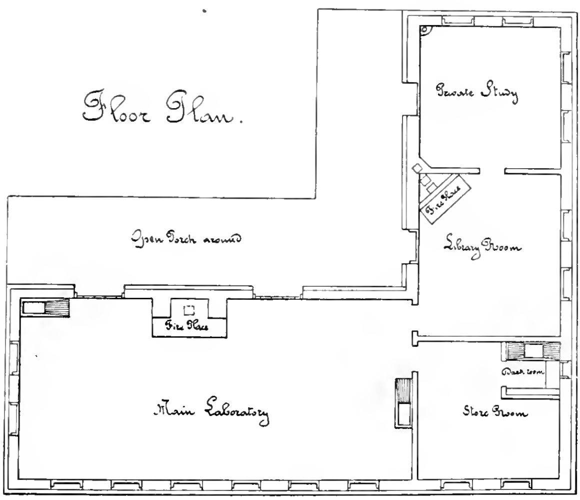
The city of Tucson, with a population of 10,000, is situated in the valley of the Santa Cruz. Its position is central with respect to the deserts of California, Mexico, Texas, New Mexico and northern Arizona. With an elevation of 2,390 feet above sea level, it has a hot, though dry and bracing, climate. The soil is a fine clay or adobe, underlaid by a white hard pan, locally known as caliche. Two miles

* 'Desert Botanical Laboratory of the Carnegie Institution,' Publication No. 6, November, 1903.

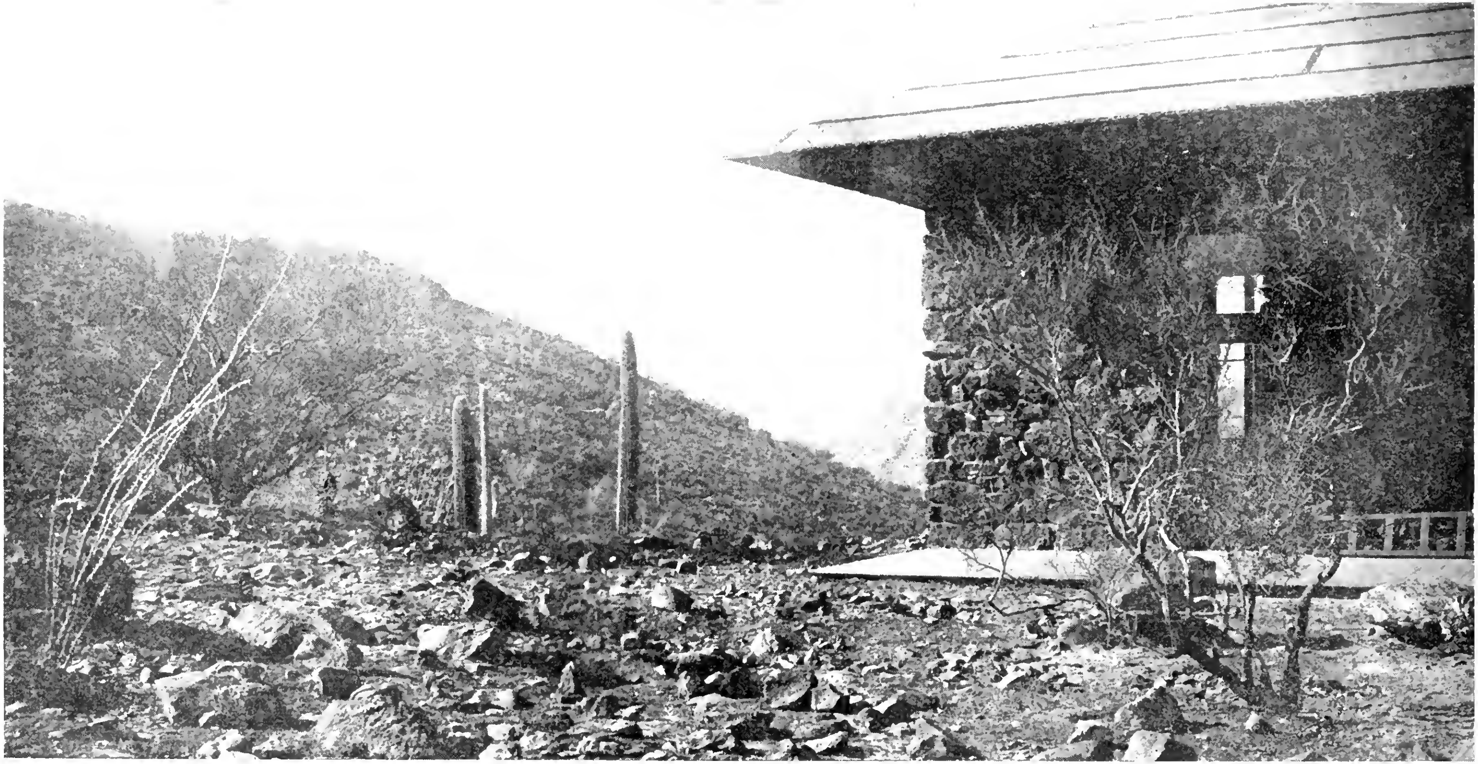


The Desert Laboratory, looking North.

to the westward are to be seen the outposts of the Tucson Mountains, rugged hills of volcanic origin. On the more gradual northerly face of one of these, on a shoulder of gentle slope, stands the laboratory, a building appropriately constructed of the volcanic rock. The style is simple and well adapted to the climate. The thick stone walls heat slowly, particularly as they are for the most part protected from the direct rays of the sunlight by an overhanging roof. This latter is so constructed as to form a large ventilated air chamber, itself a protection from the effect of intense insolation as well as affording comfort to the occupants by modifying the strong light.



The form of the building is in the shape of the letter L, with the longer outer elevation facing the north. The dimension and disposition of the space within are indicated upon the accompanying plan. The windows are abundant, and when open to the brisk winds allow a current of air throughout the building which makes one forget the heat. About this factor much misapprehension is abroad. To be sure, the mercury stands high, and a registration of 100–105°F. is not at all unusual: occasionally it is even higher, and doubtless if one did not forget to look at the instrument, still higher temperature could be discovered. Fortunately, this is just what one does. There is so little discomfort attendant upon the heat that it is usually quite disregarded, a condition happily due to the low relative humidity, which on many occasions during six weeks in July and August of this year ran down as low as 7 per cent. The only feature of discomfort to some persons is the intense illumination, and one may require dark glasses, although I personally found no discomfort even upon the mesa. On



A Corner of the Laboratory. A Palo Verde on the Right.

the volcanic hills, the dark color of the ground affords very appreciable relief.

The general laboratory is furnished with individual tables, a general work table and two sources of water supply. It should be noted that, although two miles from town and upon an elevation of 300 feet above it, there is abundant water supply. It is to the enlightened interest of the citizens of Tucson that this convenience, as well as the electrical connections, acreage and roadways, are to be credited. The immediate source of water is a 300-gallon tank, supplied from a pumping station at the foot of Sentinel Hill, which stands immediately to the southeast of the laboratory.

THE GENERAL LABORATORY.

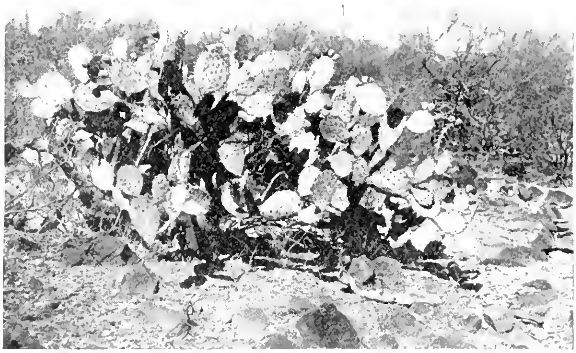
Adjoining the general laboratory is the stock room, liberally supplied with the necessities for work. This leads into a photographic dark room, with water supply, ventilation and a cement floor, and which may be used as a physiological dark room, with constant temperature.

The library, which adjoins the stock room, though at present small, contains a carefully selected lot of periodicals and books, the latter chosen with special reference to their bearing upon desert exploration and vegetation. From the library one enters the office of the resident officer, Dr. W. A. Cannon, whose generous treatment and constant sympathy, coupled with the material opportunities afforded, leave little to be desired.

The view commanded from the laboratory site is a panorama of

rare beauty. To the north lies the range of the Santa Catalina Mountains, extending through 40° of the horizon. Its rugged topography scarcely noticeable in the glare of the high sun, is thrown into bold relief when the shadows begin to lengthen. Then the dazzling purples and yellows of midday give way to the deep blues and purples of the valleys contrasted with the reddening tones of the higher slopes and ridges. The well-wooded and watered regions of this fine country are within two days' travel of Tucson, and excursions may be made thither with comparative ease.

To the east stands the rounded mass of the Rincon Mountains, the illumination of which by the afternoon sun is most remarkable. The vividness of details, the shimmer of heat, the blaze of reflected light modified by the merest veil of purple—these are faint expressions of what one quite fails to describe. To the west the desolate defiles of the Tucson Mountain, seen at short range, gives us, with the sun in the same position, a contrast picture of hard and rugged profile, dark browns and black shadows. To complete the panorama, one needs but to climb to the top of the hill, from which may be seen in

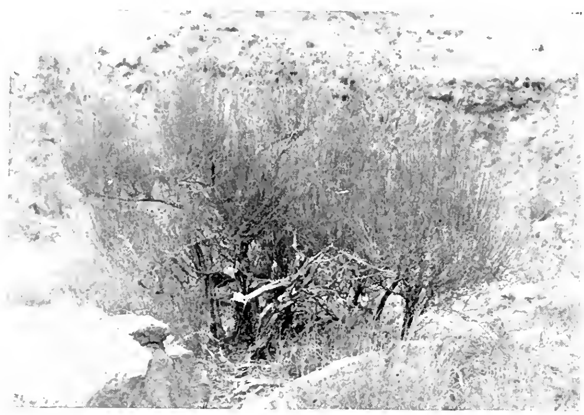


PRICKLY PEAR.

the far distance the deserts of Sonora and the malpais—the rendezvous of the few 'bad men,' now so hard to find.

Aside from the conditions for study offered by the Desert Laboratory as such, the matter with which the student is especially concerned is the plant life. In seeking for the right place to plant a laboratory for the study of desert vegetation, it is obvious that some practical conception of what such a vegetation is had to be formulated by the advisory board. It was necessary for this board to find a locality with a desert climate and possessed of as rich and varied a flora as possible,

while still of a distinctly desert character. Since it is the chief object of the laboratory to study 'drought-resistant vegetation,' it would have been absurd to put the laboratory in an out-and-out desert, and but little better to have selected a semi-arid region with a rich flora. Nor would it have been foresighted to have chosen a locality which might sooner or later be threatened by irrigation. The conditions above stated may, of course, be met in many places, but scarcely better than on the hills west of Tucson, and on the adjacent slope and mesa. The general character of the vegetation here is in the main similar to that of the mesa and rocky ridge of the whole territory between Texas and western Arizona, but is, also, within the limits of distribution of the saguaro or giant cactus (*Cereus giganteus*). It is, therefore, representative in this important respect, of a very wide stretch of country which is of an undoubtedly arid character, the plants of which are, with the supply of water derived from a meager rainfall and a little snow, able through long periods of drought to sustain their powers of growth unimpaired. A more immediate view of a few of the more striking of these desert plants will here be of interest.



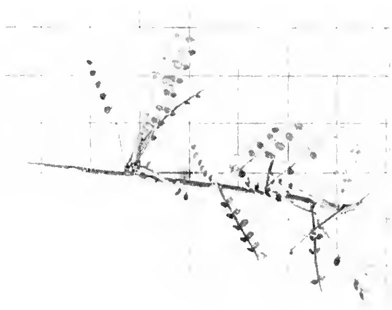
Ephedra.

The vegetation of the country about Tucson is very naturally and obviously divided into two formations which occupy, the one the level mesa, the other the rocky hills and slopes. We may consider first the mesa, where the most prominent element is the greasewood, or creosote bush (*Covillea tridentata*), a plant of rather singular aspect. The average plant in point of size stands two and a half to three feet in height. The numerous branches, which arise together from the soil, spread radially at an angle with its surface, and bear in their upper parts a meager foliage which, in times of drought, is olive-brown in color. The leaves, the form of which is peculiar to the family

(Zygophyllaceæ) of which the plant is a representative, are coated with appressed hairs and varnished with a resinous secretion. After the advent of a rain, or if watered, the plant quickly responds, the leaves becoming bright green and its delicate yellow flowers coming out in great numbers. The shrub is flat topped, and in large areas where few other so large specimens grow, the foliage of many plants lies in a uniform layer parallel to the ground. The hard twigs and branches make excellent fuel particularly for the camp cook's fire.

YELLOW-FLOWERED OPUNTIA.

Associated with the creosote bush, in numbers varying with the locality, are several species of cacti of the genus *Opuntia*, but of the type of *Opuntia arborescens*, and not possessed of the flattened branches of the common prickly pear. Of these, which are more dense tree-like in form, the one known locally as the cholla* attracts one's attention most quickly. Its smaller branches, clothed with numerous white spines, are curiously massed into formless bunches many of the smaller joints hanging down and sooner or later breaking off. Thus collect beneath the plant piles of *dejecta membra*, many dead, some dying. These broken off parts may serve to propagate the plant; when seed-pods are so cast off they more likely serve this end. In the agglomerations of branches just described birds cunningly build their nests; and these are hardly to be noticed but for the knowledge that they are frequently found in such places. The few stout ungainly stems of these plants, and, as one may say, the weird disposition of the lesser branches, glistening in their coating of gray shining spines, produce a habit which, in the language of the advertisement, is peculiar to itself. When, as often happens, the cholla has the monopoly of the situation, the desert aspect becomes very pronounced. Two other species of this type are common, the so-called *Opuntia spinosior*, with pink flowers, and another (*O. versicolor*), with yellow ones. These, however, do not show



TWIG OF PALO VERDE.

* Pronounced Cho-ya (*Opuntia fulgida*).

the peculiar massing of branches, nor are their ultimate articles so readily detached. Perhaps more interesting than all these is the little half-viny *Opuntia leptocaulis*, with stems, of scarcely the thickness of a lead pencil, interweaving among the branches of some companion plant, usually the creosote bush. It is never to my knowledge found growing except in the immediate proximity of another plant, and thus often escapes detection. It is not very well supplied with spines, and might easily be destroyed by trampling if away from the company of a plant of sturdier growth. Perhaps this is the reason why it usually is so found—it is stamped out elsewhere. Or possibly it needs the partial shade afforded it. This is a question worth an answer.

If you travel for a distance in any direction, other plants will be found. Among these are sweet-smelling acacias, ungraciously, but, I fear, not undeservedly, called cats-claws, with their finely divided leaves and small yellow pompons of flowers. The low leafless shrub *Ephedra*, with its vertical green stems which look like the scouring rush and is as rough and hard to the touch, is another—a typical desert plant if ever there was one. This plant is a relative of our yew, but is possessed of very unique characters, the description of which would take us too far into details.

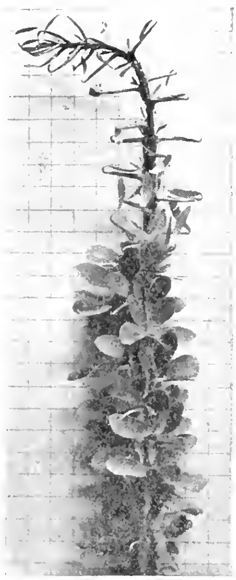
Here and there a 'salt' or 'alkali' spot is to be found. Here grow few enough plants, and these such as can endure the hardships of a most unfavorable soil, as for example *Atriplex* and *Dondia*. Near the water courses, from which for the greater part of the year water is conspicuously absent, one finds, on the other hand, larger shrubs and very small trees of *Acacia*, mesquite (*Prosopis velutina*) and a species of palo verde (*Parkinsonia*). Ten miles south of Tucson, near to the mission of San Xavier del Bac, the river bottom is occupied by a veritable forest composed wholly of large mesquite, and this the Papago Indians of the region draw upon chiefly for wood. I should mention the presence in parts of the mesa of the many low shrubs which are noticeable chiefly for their inhospitable thorniness. The palo christi (*Koeberlinia*) is an extreme type. For a crown of thorns no better material could be imagined than this.

On approaching the rocky slopes leading to the higher elevations, a different vegetation is met—different in species, but not in general character. At closer range a distinctively green note in the coloring is appreciated, which at a greater distance was a uniform brown. It is the palo verde (*Parkinsonia microphylla*), so called in the Spanish on account of the uniform green color of all its members, which gives the impression of verdure. This is a small, somewhat gnarled tree, related to our locust, of the general appearance of a trimmed orchard tree. It is usually leafless, although the younger shoots are sometimes sup-

plied with a meager foliage of compound leaves. The very small leaflets, which are foliar members of the third order, are sensitive, the pairs folding together at night and opening at dawn. Closure again occurs at the period of excessive insolation. All the ultimate branchlets taper into long stiff thorns, an example of direct metamorphosis, since they originate as normal shoots. In the absence of leaves it is evident that the chlorophyll tissues of the stems are chiefly concerned in the food-making process, which would appear true also from the fact that the smaller branches and twigs are used as green forage for horses in winter. Although a particular branch removed from the tree and regarded alone is a rather graceless object, the whole tree with its smooth green bark and gradually tapering limbs and twigs is singularly beautiful, its outline most delicate.

OCOTILLO.

Conspicuous as a member of the hillside vegetation is the ocotillo (*Fouquieria splendens*), a plant with a hypothetical relationship with the willows, but not in the least suggesting them by its habit and more obvious structures. The general disposition of its branches, which are highly suggestive of coach whips, is similar to that in the creosote bush. It is, however, a much taller shrub, with lithe, bespurred stems, bearing in spring each a brilliant mass of scarlet flowers. On the advent of the rains, the stems are quickly and completely clothed with rosettes of light green ovate leaves, each rosette in the axil of a thorn. Most interesting is the manner in which the thorns arise. The new shoots produce first the primary leaves, in the stalks of which a hard tissue is developed. Their leaf-blades rather soon wither away, and split away from the harder part of the stalks, which in this way are left as spines, in the axils of which, as above stated, the second-



TWIG OF OCOTILLO.

View on the Laboratory Hill, Giant Cacti.

ary leaves develop. The bark of the ocotillo is waxy and burns like a candle.

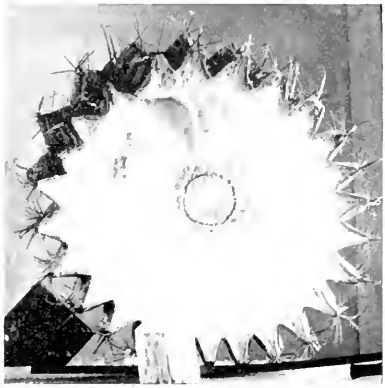
But whatever of unusual beauty or peculiarity the palo verde or ocotillo possess, the plant which of all claims and holds the attention the most constantly is the great sentinel-like saguaro or giant cactus (*Cereus giganteus*). Until middle age it is a single green fluted column, with a nature-wrought entasis, a form of severe simplicity scarcely less emphasized when, in its later growth, a few arms grow out. These are usually found at some distance below the middle point of the main shaft, and, though for the most part erect, sometimes, partly by accident, take most grotesque positions. The woody skeleton is not extensive, consisting of slender ribs which occasionally anastomose. These are used by the Papagos for palings and to form the frame of their burden frame or quijo.

The saguaro flowers in June, producing at the top of the stem a large cluster of tubular white petaled flowers in which are found hundreds of small beetles and wasps, apparently the chief agents of pollination. While the fruit is developing, the shriveled flowers, which re-

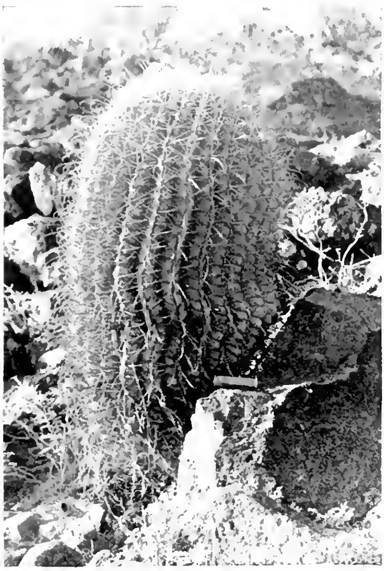
Saguaro Flower and Fruit cut Longitudinally.

Looking North from the Desert Laboratory.

main for some time attached, lend a shaggy top-knot appearance which for the while detracts from the dignity of the plant. When the fruits are ripe, the fleshy pericarps split, disclosing the crimson pulps studded with small, black seeds. The effect, at this time, if one stands at a modest range suggests a mass of crimson flowers. The fruits are sought for by Mexicanos and Papagos with an



BARREL CACTUS CUT ACROSS.

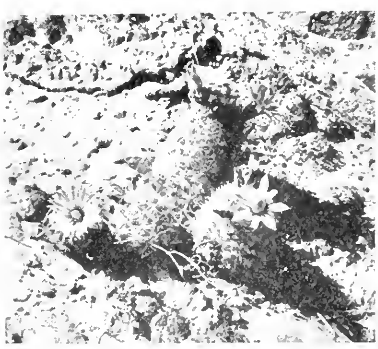


BARREL CACTUS.

avidity which to my own taste is scarcely justified by their flavor, that of a ripening fig.

Another prominent member of the cacti is the barrel-cactus (*Echinocactus Wislezeni*), which is two feet in height and eighteen inches in diameter, and is armed with large hooked spines. In this plant, as will be seen in the illustration, the rind is remarkably developed, this tissue containing about eighty per cent. water. As the sap when extracted is potable, this species, as well as certain others, is used as a source of water to quench the thirst. The prickly pears are found in profusion, and represent at least two species, one a shrubby form, four feet in height, the other a sprawler. The fruits of these two plants are also collected and eaten.

Smallest among these curious plants is a species of *Mamillaria*, each protuberance of which is surmounted by a radiating group of



MAMMILLARIA.

ENCELIA.

delicate spines. From the center of each group arises a black slender hooked spine. The flower is a relatively large one of a dainty rose color.

Space does not allow further description and the remaining shrubby vegetation, including the *Lycia* and *Celtis,* must be passed with mere reference. Two weeks after the advent of the rains the ground is clothed with many richly colored and often fragrant annuals and small perennials. Some of the latter, as for example an *Encelia* and a *Cassia,* persist through the drought, a hardiness explained in part, at least, by the felt-like protective layers on the leaves. Among the less resistant, but rapidly growing herbs are the fragrant flowered *Martynia,* with its large, double-hooked pods, and a *Tribulus,* bearing rich yellow poppy-like flowers.

With such surroundings, rich in material and opportunity, what may be accomplished at the desert laboratory? Much of the taxonomic work of this region has been done; but, in the light of modern research, much remains to do. The structure and development of scarcely one of these desert forms is properly understood, and a wide field awaits the student in these directions, while the peculiar physiology of these plants has scarcely been touched upon. Physiological and anatomical-physiological studies of wide extent may here be carried on. It is to the honor of American science that an opportunity such as this has been afforded by the Carnegie Institution.

GALILEO.

II.

By Dr. EDWARD S. HOLDEN,
U. S. MILITARY ACADEMY, WEST POINT, N. Y.

Galileo in the *Sidereus Nuncius* (1610) gives this account of the invention of the telescope:

> A report reached my ears that a Dutchman had constructed a telescope, by the aid of which visible objects, although at a great distance from the observer, were seen distinctly as if near. . . . A few days after, I received confirmation of the report in a letter . . . which finally determined me to inquire into the principle of the telescope* and then to consider the means by which I might compass the invention of a similar instrument, which, in a little while, I succeeded in doing, through deep study of the theory of refraction. . . . At length I succeeded in constructing for myself an instrument so superior that objects seen through it appeared . . . more than thirty times nearer than if viewed by the natural powers of sight alone.

On the title page of his book the telescope is described as 'lately invented by him.' This claim Galileo does not make, but in subsequent years it was charged by his enemies that he claimed credit not his due, and the charge perpetually reappears. The amazing discoveries of this memorable year are enumerated on the title page in question.

> The Sidereal Messinger (Nuncius Sidereus), unfolding great and very wonderful spectacles and offering them to the consideration of every one, especially of philosophers and astronomers; being such as have been observed by Galileo Galilei . . . by the assistance of a perspective glass lately invented by him; namely, in the face of the Moon, an innumerable number of fixed stars, the Milky Way, and nebulous stars, but especially respecting four Planets that revolve about Jupiter at different intervals and periods with a wonderful celerity; which, hitherto not known to any one, the author has recently been the first to discover and has decreed to call the Medicean Stars. (Venice, 1610.)

The surface of the moon was covered with brilliant and dark areas as the peacock's tail with spots. Perhaps the moon has an atmosphere, he says. The heights of lunar mountains can be fixed by measuring their shadows. The ashy-light of the moon ('old moon in the new moon's arms') is perhaps caused by a lunar twilight. He gives Leonardo da Vinci's explanation also—the true one—that it is caused by earth-light reflected to the moon and back to us. The stars appear as points of light, the planets as small discs. The telescope brings count-

* Galileo uses the words perspicillum, occhiale, etc., for the instrument. The word telescope was invented to describe the new instrument by Demiscianus at the request of Prince Cesi, president of the Accademia dei Lincei about 1612. The telescope itself was invented by Hans Lippershey.

less new stars to light. In the belt and sword of Orion he sees eighty stars where only seven were known before; in the Pleiades forty instead of six or seven. The Milky Way is a multitude of faint stars clustered together. The nebulæ of Orion and Praesepe are formed of stars. His discovery of the moons of Jupiter dates from January 7, 1610, when three of them were seen. They describe circular orbits about their planet. Jupiter, like each of the planets, has an atmosphere, he says. His telescope was not perfect enough to show this. It is a deduction from analogy.

New discoveries soon followed in respect to Saturn (Dec., 1610) and Venus (Jan., 1611), and they were announced in anagrams as follows:

SMAISMRMILMEPOETALEVMIBVNENVGTTAVIRAS.

ALTISSIMVM PLANETAM TERGEMINVM OBSERVAVI.

(I have observed the highest planet—Saturn—to be tri-form.)

HÆC IMMATURA À ME JAM FRUSTRA LEGUNTUR. O. Y.

CYNTHIA FIGURAS AEMULATUR MATER AMORUM.

(The mother of the loves—Venus—emulates the figure of Cynthia—the Moon.)

The latter discovery was of capital importance. If the planet Venus revolved about the sun as Copernicus had said, it must show phases like the moon. The phases, invisible to Copernicus, were revealed by the telescope. They occurred at the precise times required to demonstrate the truth of his theory. It was now no longer a theory. It was proved. From this moment no competent witness could doubt the truth of the Copernican system—Galileo less than any one.

An opportunity unique in the history of the world was presented to Galileo and he utilized it to the full. He went from triumph to triumph. The phases of Venus, the mountains of the moon, the constitution of the Milky Way, the tricorporate figure of Saturn, the solar spots, the moons of Jupiter, were death-blows to the systems of Aristotle and of Ptolemy, and were skilfully utilized to establish the system of Copernicus. That system rests, for us, not on the telescopic discoveries of Galileo, but on the working out of its details by Kepler and Newton. To the Italians of Galileo's day Kepler was all but unknown; it is even doubtful whether Galileo appreciated Kepler's splendid discoveries; it is, at any rate, certain that he never publicly mentioned them with praise.

The mere fact that the number of planets and satellites was increased by Galileo's telescope from seven to eleven was another blow to ancient superstitions. Seven was a mystic and magical number. It had relations even to Christianity, so his contemporaries thought. The seven golden candlesticks of Revelations were the seven planets. We can form some idea of the hold of certain magical numbers on the imaginations of our ancestors by remembering that when Huyghens dis-

covered a satellite to Saturn—thus raising the number of celestial bodies to twelve—he looked no more, 'because twelve was universally admitted to be a perfect number.' There were six planets and six satellites and he ventured to predict that no more would be discovered. Huyghens died in the year 1695. He was the foremost man of science on the continent of Europe.

In 1610 Galileo had seen Saturn 'tricorporate'—in December, 1612, he writes:

> Looking on Saturn I found it solitary without the assistance of its accustomed stars and, in short, perfectly round and defined like Jupiter; and such it still remains. Now, what can be said of so strange a metamorphosis? Are the two smaller stars consumed like the spots on the Sun? Have they suddenly vanished and fled? or has Saturn devoured his own children? or was the appearance indeed fraud and illusion, with which the glasses have for so long time mocked me, and so many others who have so often observed with me? Now, perhaps, the time is come to revive the withering hopes of those who, guided by more profound contemplations, have followed all the fallacies of the new observations, and recognized their impossibilities. I cannot resolve what to say in a juncture so strange, so new and so unexpected. The shortness of the time, the unexampled occurrence, the weakness of my intellect, and the terror of being mistaken, have greatly confounded me.

The explanation of the disappearance of the ansæ of Saturn's ring was not given until 1656 (by Huyghens). Galileo's telescope was not sufficiently perfect and he died without solving what was a mere riddle to him.

The spots on the sun were first seen by Galileo, though they were first described by others (Fabritius, Scheiner). In April, 1611, Galileo exhibited them at Rome to an audience of notabilities. His own observations had convinced him, he says, that the spots were real; that they were not fixed at one part of the solar globe; that they had motions; he sees no reason to doubt that they are attached to the surface of the sun; he believes that they form at the sun's surface, are dissipated and may reappear. By August, 1612, he made other observations which confirmed his earlier conjectures. Their motions prove that the sun is spherical and that it turns on an axis. He notes also that the spots all lie within certain special zones of latitude. He observes the sun by projection—by receiving its image on a sheet of cardboard. Certain large spots can be seen by the naked eye, but by an inveterate prejudice that the heavenly bodies are incorruptible, they have not been remarked; to the shame of astronomers, he says, such appearances have previously been taken for Mercury in transit over the solar disc.

Galileo's discoveries were received with incredulity by the wisest men of Italy. The warm-hearted Kepler (April, 1610) was the first to recognize 'the divinity of his genius.' Little by little they made

their way as Galileo demonstrated them triumphantly to friends and enemies. Arguments of all sorts were brought against them and against the heliocentric theory which they supported.

> Animals, which move, have limbs and muscles; the earth has no limbs and muscles, therefore it does not move. It is angels who make Saturn, Jupiter, the sun, etc., turn round. If the earth revolved, it must, also, have an angel in the center to set it in motion; but only devils live there; it would therefore be a devil who would impart motion to the earth. . . . (Scipio Chiaramonti.)
>
> Since it can be certainly gathered from Scripture that the heavens move above the earth, and since a circular motion requires something fixed around which to move . . . the earth is at the center of the universe. (Polocco, 1644.)
>
> If the earth is a planet, and only one among several planets, it can not be that any such great things have been done especially for it as the Christian doctrine teaches. If there are other planets, since God makes nothing in vain, they must be inhabited; but how can their inhabitants be descended from Adam? How can they trace back their origin to Noah's ark? How can they have been redeemed by the Savior?

The last paragraph is probably an answer to Galileo's opinion (December, 1612) that the moon and planets may be inhabited, though by creatures different from ourselves. Galileo writes to Kepler (August, 1610):

> You are the first and almost the only person who . . . has given entire credence to my statements. . . . We will not trouble ourselves about the abuse of the multitude. . . . In Pisa, Florence, Bologna, Venice and Padua many have seen the planets; but all are silent on the subject and undecided. . . . What is to be done? . . . I think, my Kepler, we will laugh at the extraordinary stupidity of the multitude. What do you say to the leading philosophers of the faculty here, to whom I have offered a thousand times to show my studies, but who . . . have never consented to look at planets, nor Moon, nor telescope? Verily, just as serpents close their ears, so do these men close their eyes to the light of truth. . . . People of this sort think that philosophy is a kind of book like the Aeneid or the Odyssey and that the truth is to be sought, not in the universe, not in nature, but (I use their own words) by comparing texts! How you would laugh, he goes on, if you heard the first philosopher of Pisa trying to 'argue the new planets out of heaven.'

While Galileo was teaching the elements of Euclid at Padua his colleague, Cremonini, was expounding Aristotle's *de Cœlo*. It was Cremonini who refused to look at the newly discovered satellites of Jupiter through the telescope, alleging as a reason that their existence was quite contrary to Aristotle's philosophy. It was the same Cremonini who, in 1619, with a dignity and firmness that must be sincerely admired, flatly refused to change the substance of his university lectures at the demand of the Grand Inquisitor of Padua. His duty was to expound the words of Aristotle as he found them, he said; he declined to teach as Aristotle's any doctrine that he did not sincerely believe to be the master's. Let this manly stand be counted off against his refusal to be convinced against authority. He is reputed to have

been the last scholastic. When he died, in 1631, there was no one to take his place. The times had changed. We are accustomed to attribute all the merit of the change to Galileo, whose career so brilliantly represents what was best in the new scientific spirit. It is impossible to declare what the movement of the world would have been had Galileo never lived. It would, perhaps, have been much the same. A company of less brilliant men would, perhaps, have done Galileo's work, taking a century for the task. Scholasticism was already moribund; the telescope was invented; the time was ripe; Kepler had already discovered his great laws of planetary motion; who can doubt that scholars would have arisen to fill the opening opportunity?

Gradually the fame of Galileo rose to a great height. He became the best known man in Europe. His lecture rooms were crowded. At Easter, 1610, he showed the Medicean stars to Cosmo II in Florence, and in May he writes a letter describing the work that he has projected—treatises on the constitution of the world, on mechanical motion, on sound, color, vision, tides, fortification, tactics, artillery, sieges, surveying, etc.* This letter soon brought an offer from the Grand Duke to appoint Galileo first philosopher and mathematician at the University of Pisa at a salary of 1,000 scudi. He is not to be obliged to reside at Pisa—and in fact his duties were usually performed by substitutes.

In July, 1610, Galileo left the service of Venice for that of Florence. It was a sad exchange for him. Venice was the only state in Italy that dared to stand up against the power of Rome. There were weighty reasons of state why the Duke of Florence could not do so. The Jesuits had been banished from the soil of Venice (1606) 'for ever.' They were all powerful in Rome and in Florence. It is evident from letters of this time that Galileo's desertion of Padua produced an unfavorable impression of self-seeking even among his friends.

Galileo's visit to Rome in March, 1611, was a veritable triumph for him. His expenses were paid by the court, he was lodged with the Tuscan ambassador, and received with the greatest honor by the Pope (Paul V.) and the cardinals, including Cardinal Barberini, the future Pope Urban VIII. To them he showed his discoveries. They were convinced and interested. At the request of Cardinal Robert Bellarmine, four learned men of the Roman College (Clavius among them) reported on what they had seen through the telescope and fully confirmed his observations. This report is of great importance, since it was, in effect, a sanction by the Church itself. Galileo was received a member of the *Accademia dei Lincei,* and its president, Prince Cesi, became his lifelong friend. The Cardinal del Monte writes to the

* Compare the letter of Leonardo da Vinci to the Duke of Milan reciting the labors that he was ready to undertake in his service.

Grand Duke of Florence (May 31, 1611) that Galileo had given great satisfaction: 'Were we still living under the ancient republic of Rome I verily believe there would have been a column on the capitol erected in his honor.' Galileo was at the top of the wave of fortune to all appearance. At this very moment, however, Cremonini's trial was going on before the Roman Inquisition and on the records is an inquiry whether Cremonini and Galileo were in any relation with each other. He was already suspected of heresy. His friendship would, even then, have been prejudicial. By 1613 Galileo was aware that there was a league of his Florentine enemies against him. In a letter to Prince Cesi he makes light of it. 'I laugh at it,' he says, but it was none the less serious. It was based on religious scruples, but stirred to action by bitter personal animosities.

Brilliant successes, like those of Galileo, raise up an army of enemies. He was haughty with his own. Sure of his talents, his fortune and his powerful patrons in church and state, he had no managements for any one. 'The wind is fair: now is the time to take in sail,' is a maxim that he would have scorned. Of Aristotle's virtues he practised magnificence, not prudence. His colleagues in the universities were mostly Aristotelians. The heretical and Arab Aristotle had been banished; the Greek Aristotle reigned supreme. Galileo handled his opponents harshly. He was proud; he had a right to be. He was haughty; it led to his fall. When certain chosen astronomers of Italy were asked in 1615 by the Holy Office to report on his system, the report was adverse. Science and pseudo-science were in conflict and the latter won. The Aristotelianism of the universities was bound closely to that of the church. In attacking the orthodox Aristotle, Galileo attacked—or was supposed to have attacked—orthodoxy itself. His enemies were vanquished in philosophy; they dragged in texts of scripture to support the weakness of their science. Galileo met them on this ground also, which was a fatal error. He was no more competent to discuss texts of scripture than they to decide upon points of science.

Father Castelli, an ardent friend of Galileo's, had been appointed to be professor of mathematics at Pisa (1613). At a dinner at the Ducal Palace (December, 1613) the conversation turned on astronomical matters. Did the Medicean stars really exist? asked the Dowager Duchess Christine. The professor of physics in the university reluctantly admitted that they did—that he had seen them. Castelli then praised Galileo's splendid discovery. The professor whispered something to the duchess to insinuate that while the discoveries might be true, the conclusion in favor of the Copernican theory was certainly contrary to scripture. Castelli was called upon to reply and made a brilliant answer. The Grand Duke and most of those present were convinced. Castelli reports all this to Galileo, and Galileo writes in reply (Decem-

ber 21, 1613) a long and eloquent letter on the subject. The original of this letter was never found, although the Inquisition made diligent search for it. Many authentic copies were circulated, however.* The question of the place of the Bible in scientific questions is discussed. Galileo is a good Catholic; the scriptures can not lie or err, he says. But the expositors are fallible. They will fall into error, nay into heresy, if they interpret Holy Writ literally. Both scriptures and external nature owe their origin to the Divine Word.

"It was necessary, however, in Holy Scripture, in order to accommodate itself to the understanding of the majority to say many things which apparently differ from the precise meaning. Nature, on the contrary, is inexorable and unchangeable, and cares not whether her hidden causes and modes of working are intelligible to the human understanding or not, and never deviates from her prescribed laws." It appears to me, therefore, says Galileo, that no effect of nature, which experience places before our eyes, or is the necessary conclusion derived from evidence, should be rendered doubtful by passages of Scripture which contain thousands of words admitting of various interpretations, for every sentence of Scripture is not bound by such rigid laws as is every effect of Nature. . . . Since two truths can obviously never contradict each other, it is the part of wise interpreters of Holy Scripture to take the pains to find out the real meaning of its statements in accordance with the conclusions regarding nature which are quite certain, either from the clear evidence of sense or from necessary demonstration. As therefore the Bible, although dictated by the Holy Spirit, admits . . . in many passages of an interpretation other than the literal one and as, moreover, we can not maintain with certainty that all interpreters are inspired by God, I think it would be the part of wisdom not to allow any one to apply passages of Scripture in such a way as to force them to support, as true, conclusions concerning nature, the contrary of which may afterwards be revealed by the evidences of our senses or by necessary demonstration. Who will set bounds to man's understanding? Who can assure us that everything that can be known in the world is known already? . . . I am inclined to think that the authority of Holy Writ is intended to convince men of those truths which are necessary for their salvation which, being far above man's understanding can not be made credible by any learning, or by any other means than revelation by the Holy Spirit. But that the same God who has endowed us with senses, reason and understanding, does not permit us to use them and desires to acquaint us in any other way with such knowledge as we are in a position to acquire for ourselves by means of those faculties, that it seems to me I am not bound to believe, especially concerning those sciences about which the Holy Scriptures contain only small fragments and varying conclusions; and this is precisely the case with astronomy, of which there is so little that the planets are not even all enumerated

This noble declaration of the independence of man's reason, written in 1613, marks the highest insight yet reached by the human spirit in this regard. It is the greatest product of Galileo's philosophical genius. It was written in haste, he says, yet its form is perfect and

* The letter was subsequently expanded and addressed in its new form to the Grand Duchess Christine (1614).

convincing. It is the weighty expression of convictions felt, pondered over and matured. It precisely expresses the attitude of the generations that followed Darwin. No considerable body of men ever held it before that day. It delighted Castelli and a few of the more enlightened of Galileo's circle. His enemies received it with breathless, uncomprehending rage. They sought for flaws in the argument and, unhappily, they had not far to seek. For, not content with these general principles, Galileo went on to explain certain passages of scripture in a fashion that, at the best, was weak and unconvincing, almost disingenuous. The famous passage in Joshua, 'The sun stood still in the midst of heaven (and hasted not to go down about a whole day)' is expounded by first suppressing the words in parentheses, next by a wire-drawn argument to prove that Joshua's command was given when the sun was near setting (which disagrees with the words purposely omitted) and that 'the midst of heaven' does not mean the place of the sun near noon, but its central place in space among the planets. Hence, says Galileo, this passage actually demonstrates that the sun occupies the center of the world, and refutes Ptolemy. The plain meaning of the verse was distorted by a wilful suppression. It is said in the XIX. Psalm 'The sun's going forth is from the end of the heaven and his circuit unto the ends of it.' Galileo explained this to mean that the sun is the nuptial bed, and the bridegroom coming out of his chamber rejoicing is the light of the sun—his rays—not the sun himself. There is not a shade of reason for this arbitrary interpretation. It is not convincing to us; it was abhorrent to his adversaries. Is it any wonder that they loudly proclaimed their intention to protect the words of the Bible from the profane interpretations of laymen? Into the quicksand of theological interpretation Galileo had no call to enter. He should have declined the controversy thrust upon him by his enemies on the simple ground that he was no more fitted to deal with theology than his adversaries with science. This was, however, not his belief, and he accepted their challenge. By so doing he quite nullified the effect of his noble stand upon general principles. Radical and bold as this stand was, he could have maintained it as Cremonini had maintained his own upon a similar issue. At this critical point in his career two roads were open. He recklessly, even presumptuously, chose the wrong one. All his tribulations are the result of this choice. In two letters of February 16 and March 28, 1615, Galileo, writing to Mgr. Dini, regrets that he has been forced to defend his system against religious scruples. In his letter to the Grand Duchess Christine he had said 'the professors of theology should not assume authority on subjects which they have not studied.' It never so much as crossed his mind that his own interpretations of the

texts of Joshua and the Psalms were like assumptions of authority. In all that follows it must not be forgotten that Galileo had the free choice of leaving the scriptural interpretations alone and of confining himself to science and to philosophical considerations of a general nature. He *chose* to enter the lists, and there is every reason to believe that he felt sure of winning.

Galileo's case recalls that of Roger Bacon, nearly four centuries earlier. The science of both these men of genius was, in the main and essentially, illuminating and correct. It was, for both of them, opposed by ignorant men who feared that which they could not understand. Both of them went out of the province in which alone they had authority, to enter another in which their contemporaries and fellows were at least as well able to judge as they. Both of them overbore and offended their colleagues by harshness. When they were brought to trial those very colleagues were, in turn, accusers, jurors and judges. A like fate befell both.

The history of Jordano Bruno does not fall within the scope of this article and need be considered only so far as it affected the contemporaries of Galileo, and Galileo himself. The following paragraphs from Draper's 'Intellectual Development of Europe' give the views of a writer who is inclined to present Bruno's history in the most favorable light. The foot notes are my own.

Against the opposition it had to encounter, the heliocentric theory made its way slowly at first. Among those who did adopt it were some whose connection served rather to retard its progress, because of the ultraism of their views, or the doubtfulness of their social position. Such was Bruno, who contributed largely to its introduction into England, and who was the author of a work on the Plurality of Worlds, and of the conception that every star is a sun, having opaque planets revolving about it—a conception to which the Copernican system suggestively leads. Bruno was born (1550) seven years after the death of Copernicus. He became a Dominican, but, like so many other thoughful men of the times, was led into heresy on the doctrine of transubstantiation.* Not concealing his opinions he was persecuted, fled, and led a vagabond life in foreign countries,† testifying that wherever he went he found scepticism under the polish of hypocrisy, and that he fought not against the belief of men, but against their pretended belief. For teaching the rotation of the earth he had to flee to Switzerland, and thence to England, where, at Oxford, he gave lectures on Cosmology. Driven from England, France and Germany in succession, he ventured in his extremity to return to Italy, and was arrested in Venice where he was kept in prison in the Piombi for six years without books, or paper, or friends. Meantime the Inquisition demanded him as having written heretical works. He was therefore surrendered to Rome, and,

* Bruno was twice disciplined for 'open and avowed' heresy during the thirteen years of his cloister life (1563–1576). He denied the personality of Christ for one thing.

† Toulouse, Paris (1579 and 1585), Oxford (1583), Wittenburg (1587), Prague (1588), Helmstadt (1589), Frankfort (1590), Marburg (1586), Venice (1592), Rome (1593). These dates correct some errors of the text.

after a further imprisonment of two years, tried, excommunicated, and delivered over to the secular authorities, to be punished 'as mercifully as possible and without the shedding of his blood,' the abominable formula for burning a man alive. He had collected all the observations that had been made respecting the new star in Cassiopeia, 1572; he had taught that space is infinite, and that it is filled with self-luminous and opaque worlds many of them inhabited—this being his capital offense.* He believed that the world is animated by an intelligent soul, the cause of forms but not of matter; that it lives in all things, even such as seem not to live; that everything is ready to become organized; that matter is the mother of forms and then their grave; that matter and the soul of the world together constitute God. His ideas were therefore pantheistic, 'Est Deus in nobis.' In his *Cena delle Cenere* he insists that the Scripture was not intended to teach science, but morals only. The severity with which he was treated was provoked by his asseverations that he was struggling with an orthodoxy that had neither morality nor belief. This was the aim of his work entitled 'The Triumphant Beast.' He was burned at Rome, February 16, 1600.

In 1612 Galileo writes to Kepler that epicycles and eccentrics are not chimerical; 'not only are there many motions in eccentrics and epicycles, but there are no other motions.' This, written three years after Kepler had sent him his Theory of Mars containing the proof of elliptic motion, shows that Galileo had not yet appreciated Kepler's revolutionary discoveries. It is doubtful if he ever did so. He makes no effective use of them in his arguments in favor of the Copernican doctrines.

In the meantime busy enemies were stirring up trouble. The letter to Castelli gave great offense. The Bishop of Fiesole became enraged at Copernicus and was much surprised to learn that he had been dead for eighty years. A Dominican friar, P. Caccini, preached a violent sermon against Galileo (1614) on the text *Viri Galilæi quid statis aspicientes in cœlum?* Ye men of Galilee, why stand ye gazing up into Heaven? Castelli was advised by the archbishop of Pisa, 'for his welfare,' 'if he wished to escape ruin,' to abandon the Copernican opinion, because that opinion, besides being an absurdity, was perilous, scandalous, rash, heretical and contrary to scripture.

Another Dominican friar, Lorini, addressed to Cardinal Mellini, president of the Congregation of the Index, a denunciation of 'the Galileists,' who hold the doctrine of Copernicus. The congregation accordingly (February, 1619) opened a secret inquiry. A copy of Galileo's letter to Castelli was examined by the consultator of the Holy

* One of them; his pantheistic ideas were, perhaps, his worst heresies in the eyes of his judges. His doctrine that space is infinite filled the pious Kepler, as well as Bruno's Roman judges, with 'horror.' Bruno's works were full of opinions that were abhorrent to all religious people of his time. He was inclined to pronounce in favor of polygamy, and he advocated a species of socialism. Religion he made essentially synonymous with intellectual culture, neglecting moral discipline and spiritual feeling.

Office, who pronounced that some phrases of it looked ill at first sight, but that they were capable of interpretation in a good sense, and did not deviate from Catholic doctrine. Caccini was summoned to Rome as a witness and gave evidence, most of which was found to be baseless (November, 1615) and was disregarded.

Early in the same year Galileo had sent copies of the letter to Castelli to friends in Rome. It was greatly admired; but his friends, one and all, strenuously advised him to keep to philosophy and to avoid religious discussion. Prince Cesi expressly warns him to avoid all mention of the Copernican theory, for Cardinal Bellarmine—a good, great and powerful prince of the Church—had told him that in his opinion the theory was heretical and contrary to scripture. Cardinals Barberini, Del Monte and Bellarmine assured Galileo's Roman friends that so long as he confined himself to scientific questions and did not enter into theological interpretations of the Bible he had nothing to fear (August, 1615). All these cardinals were very friendly to Galileo personally, and their friendship stood him in good stead. Their attitude was representative of that of the church. So long as religion was not attacked science was to be free. Any assault on doctrine was to be repelled with vigor, and at all costs. Theological interpretation was not to be permitted to laymen. That was a business reserved by the church.

A Carmelite monk, Foscarini, printed in 1615 a letter on 'the opinion of the Pythagoreans and of Copernicus of the mobility of the earth and the stability of the sun,' which was widely read and quickly came to a second edition. The Inquisition was at this time considering Foscarini's book also. Galileo felt that his presence at Rome would be advantageous, and in December, 1615, he set out provided with letters of introduction from the Grand Duke to dignitaries, including the Tuscan ambassador, Guicciardini. He was received with honor as a celebrity. With no great effort he freed himself from all personal difficulties and was able to report (February 6, 1616) that the monk Caccini had made him a formal visit to ask his pardon. On the same day he writes to the Tuscan Secretary of State, Piechena: "My business, so far as it relates to myself, is completed. All the exalted personages who have been conducting it have told me so plainly and in a most obliging manner. . . . So far as this point is concerned, therefore, I might return home without delay."

He goes on to say that it is proposed to pass judgment upon the Copernician doctrine, and that it is his conviction that he may be of use in the investigation of the matter, on account of his scientific knowledge. Accordingly he proposes to stay. He had been personally vindicated. It was his ardent desire to convert the Romans to the heliocentric theory. This he attempted by giving private lectures in

many of the great houses of Rome. His lectures began by stating all the arguments in favor of Ptolemy's system and then went on to demolish them one by one, leaving nothing standing. The lectures were admired by many great folk, and Galileo gained a great personal success for the time. His very success made his well-wishers uneasy and unquiet.

Before Galileo's visit, Fra Paolo Sarpi, professor of philosophy in Venice, distinguished as a champion of free thought and as a friend of Galileo had written: "I hear that Galileo is going to Rome, where he is invited by several Cardinals to explain his new discoveries in the heavens. I fear much that, in such a case, he may develop the reasons that lead him to prefer the doctrine of Copernicus, which will be far from pleasing to the Jesuits and other monks. They have changed what was only a question of physics and astronomy into a theological question, and I foresee, with great vexation, that Galileo, in order to live in peace, and not labeled as heretic and excommunicate, will be constrained to abjure his real sentiments on this matter. A day will come, of that I am almost sure, when enlightened men will deplore the misfortune of Galileo and the injustice done to so great a man. But, pending that day, he must suffer, and he must not complain otherwise than secretly."

The Tuscan ambassador at Rome was anxious to be rid of Galileo, and in many letters reports that it were well he returned home. He hints that Galileo's course may even bring dangers to Tuscany; he can not 'approve that we should expose ourselves to such annoyances and dangers without very good reason.' He insinuates that Cardinal Carlo de Medici may be compromised (March 4, 1616). "Galileo seems disposed to emulate the monks in obstinacy, and to contend with personages who can not be attacked without ruining yourself; we shall soon hear at Florence that he has madly tumbled into some abyss or other." "The moment is badly chosen to promulgate a philosophical idea." The Grand Duke, from friendliness to Galileo and in fear of untoward complications, gave instructions for his recall, which were conveyed in a dispatch from the ducal secretary: "You have had enough of monkish persecutions. . . . His Highness fears that your longer tarrying at Rome might involve you in difficulties, and would therefore be glad, as you have so far come honorably out of the affair, if you would not tease the sleeping dog any more, and would return here as soon as possible. For there are rumors flying about which we do not like, and the monks are all powerful." Galileo set out for Florence on the fourth of April, 1616.

Let us stop for a moment to inquire what the course of affairs would have been if Galileo, whose personal affairs were honorably concluded on February 6, had thereupon returned to Florence. He had

renewed old friendships; he had formed new ones; he was esteemed and regarded by the Pope and the most influential of the Cardinals. His enemies in Florence were utterly silenced. His accuser, Caccini, had made the humblest apologies. The Grand Duke and most of the court were his admiring friends. He had every freedom for research if only he would leave the interpretation of scripture to theological experts. 'Write freely, but keep outside the sacristy' his friends advised. Why did he remain in Rome? To convert the Congregation of the Index to Copernicanism? This would have been a triumph for science, and a personal triumph as well. The Roman Curia had absolutely no interest in science as such. They were determined that religion should not suffer. Galileo's brilliant lectures were not conceived in the spirit that convinces. He silenced opposition by sarcasm. A second crisis in Galileo's affairs dates from this period (February, March, 1615).

Before this date momentous action had been taken by the Inquisition. On February 19 the Qualificators of the Holy Office had been summoned to give their opinion on two propositions based on Galileo's treatise on the Solar Spots:

I. That the sun is the center of the world and immovable from its place.

II. That the earth is not the center of the world, nor immovable, but moves, and also with a diurnal motion.

The Qualificators were to give their opinion as theological and philosophical experts, and gave it four days afterwards. The astronomer Riccioli declares that the opinions of astronomical experts were also obtained and that the judgment of the Holy Office was based upon them (Delambre: *Histoire de l'Astronomie Moderne,* i., 680). There is no reason to doubt the assertion. It is exceedingly important as showing that the Inquisition took the best expert advice known to them before action. This significant fact is not mentioned in any of the Warfare-of-Science books, nor even by so careful an historian as Gebler.*

The scientific value of the expert astronomical opinion was, of course, exactly *nil.* It was given, probably, by Aristotelians, personally inimical to Galileo, and fully committed to the Ptolemaic system. It was, equally of course, adverse to Galileo. They may well have

* Gebler records, however the action of Cardinal Gaetano who, in 1616, applied to Thomas Campanella, a learned Dominican and a friend of Galileo's, for an opinion upon the relation of the Copernican theory of Holy Scripture. Campanella's 'Apology' for Galileo was all in his favor and reconciled, in form at least, Copernican science with the Bible. It was overweighed by other reports. It is worth recording that Campanella was not permitted to publish this 'Apology' in Italy and was obliged to disavow an edition which appeared at Frankfort.

quoted the dictum of Tycho Brahe that the system of Copernicus was 'absurd and contrary to Holy Writ' since the judgment recites these very words. On March 5, 1616, the 'De Revolutionibus' of Copernicus and another work by Diego di Zuniga were suspended by the Congregation of the Index 'until they be corrected,' and Foscarini's book was 'altogether prohibited and condemned' as well as 'all other works' in which the Copernican opinion is taught. On February 25 the Pope directed 'Cardinal Bellarmine to summon before him the said Galileo and to admonish him to abandon the said opinion; and, in case of his refusal to obey, that the Commissary is to intimate to him, before a notary and witnesses, a command to abstain altogether from teaching or defending this opinion and doctrine, and even from discussing it; and if he do not acquiesce therein, that he is to be imprisoned.' This document is followed in the Vatican MS. by another: "Friday, the 26th (February, 1616). At the Palace, the usual residence of the Lord Cardinal Bellarmine, the said Galileo, having been summoned and brought before the said Lord Cardinal, was in the presence of the Most Rev'd Michael Angelo Segnezzio, . . . Commissary-General of the Holy Office, by the said Cardinal warned of the error of the aforesaid opinion and admonished to abandon it; and immediately thereafter, before me and before witnesses, the Lord Cardinal Bellarmine being still present, the said Galileo was by the said Commissary commanded and enjoined . . . to relinquish altogether the said opinion . . . ; nor henceforth to hold, teach or defend it in any way whatsoever, verbally or in writing; otherwise proceedings would be taken against him in the Holy Office; which injunction the said Galileo acquiesced in and promised to obey. Done at Rome in the place above said, in presence of (two persons named) witnesses." This annotation was long supposed to have been fabricated in 1632 to meet new conditions then arising. It is, however, entirely genuine. (Gebler's 'Galileo,' Appendix III.)

The exact wording is to be noted. Upon this admonition the subsequent fate of Galileo hangs.

(To be continued.)

HOW IMMIGRANTS ARE INSPECTED.

By Dr. ALLAN McLAUGHLIN,
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Inspection of our immigrants may be said to begin in Europe. The immigrant usually buys his steamship ticket in his native town from an agent or subagent of the steamship company. The agents of the best steamship lines are held responsible by the company, for the passengers they book for America, and if they ship one of the excluded classes they are likely to lose their agency. This makes the agent examine the applicants for tickets, and probably quite a large number of defectives are refused passage by agents of the first-class lines. These defectives then usually try some less particular and smaller lines and take chances of escaping inspection at the Canadian or Mexican borders.

The next scrutiny to which the immigrant is subjected is that of the steamship authorities at the port of embarkation. This was formerly a perfunctory examination, and is so still, as far as some lines are concerned, but first-class lines, notably the English and German, examine the immigrants carefully and with due regard for our laws. The strict enforcement of our laws, and especially the imposition of one hundred dollars fine for bringing to our ports any case of a contagious character, have occasioned some improvement in the inspection made by ships' doctors at European ports. At the port of embarkation the immigrants' names are recorded upon lists or manifests, each list containing about thirty names. After each name the steamship officials are required by law to record answers to a certain number of queries relating to the immigrant.

Section 12 of the act of 1903 provides that the manifests shall state, in answer to the questions at the top of the manifest sheet:

> The full name, age and sex; whether married or single; the calling or occupation; whether able to read or write; the nationality; the race; the last residence; the seaport of landing in the United States; the final destination, if any, beyond the port of landing; whether having a ticket through to such final destination; whether the alien has paid his own passage, or whether it has been paid by any other person or by any corporation, society, municipality, or government, and if so, by whom; whether in possession of thirty dollars, and if less, how much; whether going to join a relative or friend and if so, what relative or friend, and his name and complete address; whether ever before in the United States, and if so, when and where; whether ever in prison or almshouse or an institution or hospital for the care and treatment of the

insane or supported by charity; whether a polygamist; whether an anarchist; whether coming by reason of any offer, solicitation, promise or agreement, expressed or implied, to perform labor in the United States, and what is the alien's condition of health, mental and physical, and whether deformed or crippled, and if so, for how long and from what cause.

The master or first officer and the ship's surgeon are required by the same law to make oath before an immigration officer at the port of arrival that the lists manifests are to the best of their knowledge and belief true, and that none of the aliens belongs to any of the excluded classes. Each alien is furnished with a card, with his name, the number of the list on which his name appears and his number on that list. The cards of minor children are given to the head of the family. These cards are valuable and necessary for identification, and facilitate inspection at the port of arrival.

The condition of the steerage quarters of a modern steamship depends largely upon the age of the ship and the degree of overcrowding. The steerage of a first-class ship of recent construction will afford accommodations equal to those accorded second cabin passengers on less progressive lines. First-class lines are careful also to prevent overcrowding. On some of the smaller and older ships the accommodations are limited, and overcrowding is permitted. But it is safe to say that the worst steerage accommodations to be found on any ship entering New York harbor to-day are infinitely better than the best afforded by the sailing vessels or old 'side wheelers' of the past.

On entering New York harbor the ocean liners are boarded by the state quarantine authorities, and the immigrants inspected for quarantinable disease, such as cholera, small-pox, typhus fever, yellow fever or plague. Then the immigrant inspectors and a medical officer of the Public Health and Marine Hospital Service board the vessel and examine the cabin passengers, paying particular attention to the second cabin. This cabin inspection is very necessary, and, before its institution, the second class cabin was the route most often employed by persons who found it necessary to evade the law. After the completion of the cabin inspection the ship's surgeon reports any cases of sickness among the aliens in the ship's hospital. The medical inspector examines these cases and later arranges for their transfer, if deemed advisable, from the ship to the immigrant hospital. The immigrants are then taken from the ship upon barges to the immigrant station, Ellis Island.

The medical examination at Ellis Island is conducted according to a system which is the result of many years of development. The doctors work in pairs, and divide the inspection between them. The immigrants, coming in single file, are examined for certain defects by the first doctor, who detains each one long enough to keep a space of

ten to fifteen feet between the immigrants. The second doctor, placed about thirty feet from the first, disregards that part of the examination entrusted to his colleague and confines his examination to such defects as are not looked for by the first doctor. The file of immigrants makes a right-angle turn just as it reaches the second doctor and this enables the examiner to observe the side and back of the passenger in the shortest time possible.

The examiners follow a routine in this examination, and the scrutiny begins at the approaching passenger's feet, before he comes within fifteen feet of the examiner. The examiner's scrutiny beginning at the feet travels upward, and the eyes are the last to be inspected. In this way, lameness, deformity, defective eyesight (through efforts to adjust his vision, after making the turn, to a new course) are detected. The gait and general appearance suggest health or disease to the practised eye, and aliens who do not appear normal are turned aside, with those who are palpably defective, and more thoroughly examined later.

The medical examiners must ever be on the alert for deception. The nonchalant individual with an overcoat on his arm is probably concealing an artificial arm; the child strapped to its mother's back, and who appears old enough to walk alone, may be unable to walk because of infantile paralysis; a case of favus may be so skilfully prepared for inspection that close scrutiny is required to detect the evidences of recent cleansing, and a bad case of trachoma may show no external evidence and be detected only upon everting the eyelid.

After the last alien in line has passed the doctor, the suspected ones turned aside are thoroughly examined, idiots and those suffering with a loathsome or dangerous contagious disease are certified and sent to the board of special inquiry. Cases not deemed fit to travel are sent to the hospital, and cases with some disability likely to make them a public charge are certified accordingly and also sent to the board of special inquiry. Minor defects, such as anemia, loss of an eye, loss of a finger, poor physique, low stature, etc., are recorded on the alien's card and he is allowed to go to the registry clerk and immigrant inspector in charge of the manifest, who takes the defect into consideration as contributory evidence, and may or may not send him to the board.

After passing the doctors, the immigrants are grouped, according to the number of their manifest sheet, into lines of thirty or less. At the head of each line is a registry clerk, or interpreter, and an immigration inspector. The clerk, or interpreter, interrogates each alien, and finds his name, and verifies the answers on the manifest sheet before him, and if, in the opinion of the immigrant inspector, the immigrant is not clearly and beyond doubt entitled to land, he is held for the consideration of the board of special inquiry. A board of spe-

cial inquiry according to the law of 1903 'consists of three members selected from such of the immigrant officials in the service as the commissioner general of immigration, with the approval of the secretary of commerce and labor, shall designate as qualified to serve on such boards.' "The decision of any two members of a board shall prevail and be final, but either the alien or any dissenting member of said board may appeal through the commissioner of immigration at the port of arrival, and the commissioner general of immigration to the secretary of commerce and labor, whose decision shall then be final, and the taking of such appeal shall operate to stay any action in regard to the final disposal of the alien, whose case is so appealed, until receipt by the commissioner of immigration at the port of arrival, of such decision." To this 'board of special inquiry' are sent the aliens certified by the medical officers as suffering from loathsome or dangerous contagious disease, idiocy, epilepsy and insanity.

In cases so certified the law is mandatory, and the medical certificate is equivalent to exclusion, the board simply applying the legal process necessary for deportation. Aliens certified by the medical officers as suffering from disability, likely to make them public charges, are also held for examination before the board of special inquiry. The board in these cases takes into consideration the medical certificate and such evidence as may be adduced by the alien or his friends which, in the opinion of the board, would offset the physical disability. In these cases the board has full discretionary powers, and in a great majority of instances the alien is admitted. Those certified as defective by the doctors group themselves naturally into four classes, and the following table indicates the disposition of such cases by the boards of special inquiry at New York during a fairly representative month:

Disposition of Immigrants Certified at Ellis Island, N. Y., Month of October, 1903.

	Class I. (Dangerous Contagious.)	Class II. (Insanity and Idiocy.)	Class III. (Loathsome.)	Class IV. (Likely to become a Public Charge.)
Cases pending beginning of month..	10	0	0	30
Cases certified during month..........	83	1	1	393
Total to be accounted for................	93	1	1	423
Cases deported................................	61	1	1	30
Cases landed	4	0	0	349
Cases pending close of month.........	28	0	0	44

Immigrants not detained for the board of special inquiry have their money changed into United States currency, and buy their railroad tickets, under the supervision of government officers. If they are destined to points beyond New York City, government supervision is maintained until they are taken to one of the great railroad terminals

and placed upon the waiting train. These precautions are taken to protect the immigrants from the boarding house 'runners' and other sharpers who lie in wait for them at the Battery. Aliens detained as not clearly entitled to land are brought before the board, and, if the evidence is complete, either deported or discharged. When the evidence is incomplete, the immigrant is detained pending the verification of his story, or the arrival of his relatives or friends. All cases are disposed of as rapidly as possible, and immigrants are detained the minimum amount of time required for procuring and carefully considering the evidence in the case. Those ordered deported are returned to the ship as soon as possible after the decision is rendered, providing no appeal is made.

Missionaries and representatives of various religious denominations and societies have offices upon Ellis Island and render valuable assistance to the immigrant. They provide temporary shelter and protection for discharged aliens, and direct them to legitimate employers of labor. In this way they relieve the government of caring for many temporarily detained aliens, especially young women traveling alone. They write letters and send telegrams to the friends of the detained immigrants, and assist them in many other ways.

The fine adjustment of details and perfection of system which enable the federal officers at Ellis Island to examine, under our laws, thousands of aliens each day must be seen to be fully appreciated. Nor is this careful and strict execution of our laws limited to Ellis Island. The writer has roughly described the inspection at New York, because it is our largest port of entry, but the same attention to detail and strict enforcement of laws and regulations can be said to exist at all our ports, and an investigation, by any one interested, will reveal the fact that not only are the laws for our protection strictly enforced, but their enforcement is marked by humane and kindly treatment of the alien.

ON THE RELATIONS OF THE LAND AND FRESH-WATER MOLLUSK-FAUNA OF ALASKA AND EASTERN SIBERIA.

By WILLIAM HEALEY DALL,
SMITHSONIAN INSTITUTION.

HAVING recently completed a census of the land and fresh-water mollusk-fauna of Eastern Siberia and Alaska, together with a discussion of the relations of its elements, it seemed that a summary of the results in their bearing on geographical distribution of animal life in the boreal regions might have some interest for the readers of the POPULAR SCIENCE MONTHLY.

In the region north of latitude 49° the molluscan population of North America is rather scanty. For distributional purposes it must be divided into two series, one containing the aquatic forms and the other the land shells. The distribution of water animals is carried on by different means from those influential in the dispersal of terrestrial forms, and any discussion which combined the two without distinction would be liable to contain errors of fact and deduction.

The vast territories under consideration have a number of drainage systems which in the tabulation of species should be distinguished. The chief of these are:

1. *The Labradorian.*—This comprises the area of drainage into Ungava Bay and the Atlantic north of the straits of Belleisle and the 'Height of Land,' including the Labrador coast and the northeastern part of the Ungava District of the Dominion of Canada.

2. *The Canadian.*—This system comprises the drainage of the St. Lawrence and the Great Lakes south and east from the 'Height of Land,' including the island of Anticosti.

3. *The Hudsonian.*—This, the largest system of all, includes the entire area draining into Hudson Bay, including Keewatin, the southeastern corner of the Mackenzie District, eastern Athabaska, the whole of Saskatchewan, the southeastern two-thirds of Alberta, Assiniboia and Manitoba, the drainage area of the Red river of the north in the Dakotas, and northeastern Minnesota, all of Ontario, Quebec, and Ungava north and west of the 'Height of Land.'

4. *The Mackenzian.*—This vast system includes the basin drained by the Mackenzie river and its tributaries, covering northwestern Alberta, northeastern British Columbia, and the northwestern two thirds of Athabaska and the Mackenzie District.

5. *The Columbian.*—This includes the coast drainage of British Columbia and Southeastern Alaska, the basins of the Fraser and Columbia rivers, the coastal part of the State of Washington, and the northern part of Idaho and Montana, west of the Selkirk Range and its more southern equivalents in the Rocky Mountain region. The northwestern extension of this system in Alaska, between the Coast Ranges and the sea, including the Alaska Peninsula and the Aleutian Islands, being really an extension northwestward of the Columbian system, might perhaps for convenience be called the Alaskan subregion.

6. *The Yukonian.*—This system includes the entire drainage of the Yukon river, the tundra north of it and the basin of the Kuskokwim; or all of Alaska north, northwest and west of the Alaskan range, as well as that of the basin east of the Coast ranges drained by the Yukon and its tributaries.

We know through the researches of General G. K. Warren, U. S. Engineers, that a considerable portion of the original Mississippi drainage near its former headwaters has, through changes of level of the earth near the 49th parallel, been captured by the Hudsonian drainage system, and it is not unreasonable to suppose, that a certain proportion of the Mississippi fresh-water fauna was captured with the streams in which it lived. Some such supposition seems necessary to explain the far northern extension of certain Mississippi Valley species in the Hudsonian region, while other drainages equally suited to their inhabitation are destitute of them.

Another factor in the distribution of land as well as fresh water shells is the former existence of a continental ice-cap by which the entire mollusk fauna of the region occupied by ice would be exterminated; though, in the interglacial periods, the external fauna might advance as the ice retreated, only to be driven out again on the return of the ice. Such fluctuations have been well shown, by the researches of Dr. Coleman, of Toronto, to have occurred in the valley of the Don, near that city.

The vast territories included in these drainage systems are, it is true, only partially and imperfectly explored for mollusks. Yet certain portions of them are tolerably well known and the uniformity imposed on the fauna by its high northern position and unvaried conditions, leads to the belief that, while much is yet to be known in tracing out the details of distribution, little is to be expected in the way of absolutely new species, even from this immense territory yet to be explored.

It would be rash to conclude that nothing new remains to be found, but our expectations should certainly be moderate.

There are a few characteristic fresh-water forms in Greenland,

Labrador and the Hudsonian region, but in the main, the molluscan population of the waters of the region described may be regarded as a northward extension of the Northeast American and Mississippi Valley faunas, diminished by the elimination of all the less hardy species and reinforced by the addition of a small number of circumboreal forms. The total fresh-water fauna comprises 138 species, of which 90 occur in the Hudsonian system, but only 23 extend to the Mackenzie basin, though the Yukon system may boast of 29. Some eccentricities of distribution will be referred to later.

The distribution of land shells is not affected to any serious extent by rivers or streams, but is doubtless, in the main, the result of the slow movement of individuals.

The pulmonate fauna of Alaska is composed of four elements; contributions from the faunas of Asia, of the Pacific Coast region of America, of the Hudsonian or Canadian region, and of the special circumboreal or common subarctic fauna of the whole northern hemisphere.

Differences of latitude mean for the snail not so much differences of temperature corresponding to the latitude. as differences of the annual active period, which diminishes as one proceeds northward. Snails at Point Barrow (and there are such) must remain in a state of hibernation at least nine months in the year, and I suspect that this more probably brings a limiting strain on the vitality of the organism, than would the mere occurrence at times of a specially low temperature.

The Alaskan land shells number 86 species, of which 16 are circumboreal, and the same number (though not all the same identical species) are common to the northeastern part of Siberia. Fifty species are held in common with the Pacific fauna, while 34 are part of the Yukon fauna which is so intimately allied to that of the Hudsonian region. These latter two groups are limited by topographic features. Thus the fauna of the Hudsonian region, in constantly diminishing number of species, is extended to the northwest through the Yukonian region north of the Coast range and the Alaskan range, to Bering Sea on the west and the Arctic coast on the north.

In like manner the fauna of the Columbian region of the Pacific Coast, is extended along the Alaskan coast and islands south and west of the two ranges mentioned, and between them and the sea. Some of the most characteristic and larger species are cut off in their northwestern extension by the area near Mount St. Elias, where along one hundred miles of coast immense glacier fields extend to the very border of the sea. The last representatives of this fauna disappear among the eastern Aleutian islands. In British Columbia a few species belong to the Valley region between the Rocky and the Cascade Mountains, and do not reach the sea coast, but these are too few to

modify essentially the general rule, and like the valleys themselves, these species disappear a short distance north of the 49th parallel. I was able to show, some thirty-five years ago, that in a broad way the distribution of the birds and plants presents analogous features.

Fauna of Northeastern Asia.

The land shell fauna of the northeast extremity of Asia has little individuality. but represents a mingling of the depauperated extremes of the faunas of northeast China and of Europe with that series of species which is sometimes called the circumpolar or circumboreal fauna.

Much of the apparent poverty of the fauna may be due to insufficient collecting, but even when the most generous allowance for this factor is made, it still remains certain that the molluscan population is far less in variety than might reasonably be expected.

The palaearctic fauna of Europe appears to extend clear across Northern Asia, losing a large proportion of its species on the way, until (if the circumboreal species be excluded) only about thirty species reach the headwaters of the Lena and the barrier of the Stanovoi range. A very remarkable local fauna exists in the great 'Relictensee' of Siberia, Lake Baikal, but it does not appear to have tinctured the East Siberian fresh-water fauna outside of that lake, to any appreciable extent. It is possible that the comparatively recent emergence of a large part of Eastern Siberia from the sea, and the presence of the vast desert region to the south and west, may enter into the explanation of this sparse shell-fauna, as well as of some of the peculiarities of the Baikal faunula.

Southeast of the Stanovoi range we find between the mountains and the sea, the valley of the Amur and several smaller valleys, such as the drainage-basins of the Ud and the Tugar. To the southwest the sources of the Amur emerge from the deserts of Gobi and Dauria, and along the line of these water courses has crept a certain number of molluscan forms intimately related to or identical with those of Mongolia, China and the Orient. This forms the second element of the fauna of Northeast Siberia.

The number of purely endemic species is remarkably small and a portion of those claimed to be of this character are probably mere local mutations of widespread palearctic forms already known. Yet it would seem as if a more thorough exploration must add largely to the species now known, and it is almost incredible that the luxuriant fertile valleys of Kamchatka and the innumerable streams and lakes of that country should not be well populated with mollusks.

There are a few species which seem to be common to the shores of Bering Sea, both Asiatic and American, such as *Succinea chrysis, Pyramidula pauper, Punctum conspectum,* and *Anodonta beringiana.*

There is one local species, *Eulota weyrichi,* known only from Sakhalin Island; and another, *Helicigona subpersonata* from the valley of the Ud. Three forms of *Vivipara* (of which two are probably variants of Chinese forms) are the only exclusively local species of the vast Amur Valley, or drainage, not known from other regions. Nine specially Kamchatkan species have been described, but about half of them are doubtfully distinct.

The total number of land and fresh-water mollusks known from the Amurland, Sakhalin, Kamchatka, the Chukchi peninsula, and the Asiatic coast north of the Amur and east of the Stanovoi range, is only eighty-one. Of these thirteen are circumboreal species, and twelve are supposed to be locally peculiar. Of the remainder

Europe and West Siberia contribute.............	55	per cent.
Northeast China contributes.....................	22	"
In common with America there is................	13	"
Erratic species	10	"

Of these erratic species a few may be especially mentioned. *Margaritana margaritifera,* as is well known, is absent from the whole of the great northern central region of North America, though it appears in the Lower Saskatchewan, the sources of the Missouri and in eastern Canada, while on the Pacific it ascends at least to latitude 56° N. In eastern Asia it is known from Kamchatka, Sakhalin Island, the upper portion of the Amur basin, and southern Mongolia—but I find no authoritative record of it thence westward to Northern and Middle Europe. Schrenck did not find it on the lower Amur.

Phisa fontinalis is reported from the upper Amur and (in a duck's crop) the desert of Dauria, but is not known from Siberia proper, though common in Europe. There is an entire absence of typical *Physa* throughout East Siberia, so far as reported; and only one species of *Ancylus* or *Unio* is known from east of the Yenisei river of Siberia.

Aplexa hypnorum is known from Northern Europe, Western Siberia and the Chukchi peninsula, but has not been reported from Eastern Siberia, or the Amur, though abundant in Alaska, and reaching on the Taimyr peninsula to 73° 30′ North Latitude.

Zoögenites harpa is known from Northeastern Scandinavia in Europe; from Northeastern America, the Hudson Bay territory and Southeastern Alaska, in America; but in Siberia it is recorded only from the easternmost margin; the Chukchi peninsula, Bering Island, Kamchatka and the lower Amur. These singularities of distribution must await much more extended knowledge before they can be adequately discussed, but it is believed that to some extent they are due to the transgression of the sea, or of glacial ice, over part of the area in which a species might naturally be expected to occur, thus delaying the occupation of the entire region by the species concerned.

EXAMINATIONS, GRADES AND CREDITS.

By PROFESSOR J. McKEEN CATTELL,

COLUMBIA UNIVERSITY.

THE determination of individual differences, the improvement of useful traits and the assignment of men to the work for which they are fit are among the most important problems in the whole range of pure and applied science. The extraordinary growth of the material sciences with their applications during the nineteenth century requires as its complement a corresponding development of psychology. It would under existing conditions be intolerable to erect a building without regard to the quality and strength of materials, to use at random a wooden beam or a steel girder; yet we often do much this thing in selecting men for their work and adjusting them to it.

In examinations and grades we attempt to determine individual differences and to select individuals for special purposes. It seems strange that no scientific study of any consequence has been made to determine the validity of our methods, to standardize and improve them. It is quite possible that the assigning of grades to school children and college students as a kind of reward or punishment is useless or worse; its value could and should be determined. But when students are excluded from college because they do not secure a certain grade in a written examination, or when candidates for positions in the government service are selected as the result of a written examination, we assume a serious responsibility. The least we can do is to make a scientific study of our methods and results.

Grades assigned to college students have some meaning, though just what this is remains to be determined. Dr. Wissler* has shown that there is a decided correlation in the standing in different subjects. A man who receives a high grade in Latin is likely to receive a high grade in Greek, and almost as likely to receive a high grade in mathematics or gymnastics. This seems to indicate that the grades are assigned for moral traits, or for the general impression made by the man, as much as for ability and performance in a given subject. Professor Thorndike and his students† have found a similar relationship in school grades and in the New York State Regents' examinations. Professor Dexter‡ has shown that a man who is given a high

* 'The Correlation of Mental and Physical Tests,' Monograph Supplement to *The Psychological Review*, No. 16.

† Summarized in 'Educational Psychology,' Lemcke and Büchner, 1903.

‡ 'High Grade Men in College and Out,' POP. SCI. MON., March, 1903.

standing in college is more likely than others to find his name in 'Who's Who in America.' Phi Beta Kappa men (on the average the upper seventh of the class) are twice as likely to be there as others, and the first man in his class is five times as likely.*

It is evident that subjects differ greatly in examinability. The results of an examination in mathematics, for example, can be graded with considerable accuracy; they give fairly definite information as to the man's mathematical aptitudes, and mathematical ability is largely innate, so that here the boy is father to the man. The mathematical tripos at Cambridge is a real test. Of the fifty senior wranglers in the first half of the last century a very large number have attained eminence. For example, two of them, Sir George Gabriel Stokes and Dr. N. M. Ferrers, who died within a month preceding the writing of this paragraph, maintained both in mathematical performance and general efficiency the position of, say, first in a hundred given them as the result of a student examination. Two facts should, however, be borne in mind. The senior wrangler is given great opportunity by being made a fellow, and the examination is on three years of solid work. The results of examinations in scrappy courses lasting half a year are not nearly so valid.

Subjects such as literature and psychology do not lend themselves to written examinations so well as mathematics. I have had the same papers in psychology graded by different examiners and have found great variations in the results. There is some validity in the order of excellence, but scarcely any in the absolute grades, the variation of the grades for the same paper by different examiners being as large as the variation of different papers by the same examiners. I have not, however, confirmed this result by sufficient data. One of our courses in psychology is given by different instructors, each of whom sets and grades papers for the same student. The grades assigned are A, B, C, D and F—excellent, good, fair, poor and failure. Four instructors gave twenty-one men a total of 15 A's, 38 B's, 27 C's, 4 D's and 1 F. When, however, we average the grades of the four instructors, we get 3B + 17C + and 1D +. All the grades are alike within the unit used, except four, and the probable errors of three of the four show that they are as likely as not to fall within this grade, while the probable error of the remaining grade gives it but moderate validity.

It seems scarcely possible to determine what students are fitted for a college course by means of a written examination; and I fear

* It must, however, be remembered that the kind of people who are put in a book such as 'Who's Who' are largely those who talk about things rather than those who do things—the class that receives part payment for its services in notoriety.

that the systematization of entrance examinations under the auspices of a board will be harmful to secondary education.* The German method, which has made some progress here, of leaving the decision to the school seems much better. If we can not accept the recommendation of the school, I should prefer to see the candidate passed upon by two psychological experts. If their independent judgment agreed, I should have more confidence in this than in the results of any written examination. In general, I should admit to college any students who were not pronounced unfit by expert opinion, dropping of course those who subsequently proved themselves unfit. Requiring all students to pass an examination in Latin composition and the like is as out of place in a modern university as an ichthyosaurus on Broadway†.

Our college entrance requirements and examinations are a serious injury to secondary education, and they select very imperfectly the men who should have a college education. Of 262 students who entered Columbia College in 1900, only 50 completed the regular four-year course in the college. Civil service examinations often exclude the fit from the public service. In Great Britain the method is carried to an extreme, and the results depend as much on the coach as on the candidate. Almost anything is better than appointments for party service; but past performance, character, habits, heredity and physical health are much more important than the temporary information that can be but imperfectly tested by a written examination. I should not be willing to select a fellow or an assistant in psychology by such a method, and to select a professor would be nearly as absurd as to choose a wife as the result of a written examination on her duties. To devise and apply the best methods of determining fitness is the business of the psychological expert, who will probably represent at the close of this century as important a profession as medicine, law or the church.

I am at present working at the problem of assigning grades for moral, mental and physical traits‡, but shall here confine myself

* Since this was written Professor Thorndike has compiled statistics, not as yet published, which indicate that students who pass these examinations with the lowest grades are as likely to do well in college as those having much higher grades. Those rejected would probably do equally well.

† In the discussion now in progress at Cambridge concerning the requirement of Greek at entrance, Professor Jebb ridiculed New Zealand as a Greekless land, because one of its citizens is alleged to have called Andromache 'Andromach.' Professor Jebb in his speech called New Zealand a part of Australia; yet he does not regard himself as illiterate.

‡ Cf. articles in *Science* (N. S. **17**: 561–570, 1903) and *Am. Jour of Psychol.* (**14**: 310–328, 1903).

to a discussion of college grades. The literature is very scanty. I can only refer to two papers*, both of which are slight.

Grades are usually assigned on a scale of 100, some institutions, as Harvard and Columbia, reporting only the five groups into which the men are divided. The starting point in all grades is the fact that the written papers or the results of the term's work can be arranged more or less accurately in the order of merit.† The assignment of quantitative grades to a qualitative series or its division into groups is usually done in an arbitrary manner, and, so far as I am aware, no attempt has hitherto been made to assign probable errors. It is obvious that our grades should be standardized. Our colleges are in the position of a grocer who should let each of his clerks give to customers without weighing and without knowledge of market prices what he believed to be a dollar's worth of tea.

The simplest method of assigning grades is to arrange a hundred papers as nearly as may be in the order of merit and to give the poorest paper the grade 1, the next poorest the grade 2, and so on, until the best paper receives the grade 100. The 100 cases would not be exactly representative of the entire group with which we are concerned; but if we had 100,000 cases, the error from this source in giving the poorest 1,000 the grade of 1, etc. would be entirely negligible. It is possible to calculate how likely it is that in a random group of 100 cases we should find two, three or more men to whom the lowest or any other grade should be assigned. Each instructor forms a rough estimate of the group of students with which he is concerned, and can with a probable error that might be determined assign its place in the series to each case.

If men are arranged in this way in the order of merit and each is assigned his position in the series from 1 to 100, the differences between them will not be equal. If a hundred men are placed in a row according to height, the line passing along the tops of their heads will not be a straight line. The men in the middle of the row will differ but little from one another, and the differences will become continually greater towards the ends. Fig. 1 (page 366) shows the approximate distribution in stature of 1,052 English women, measured for Professor Karl Pearson. Their average height was about 5 feet 2½ inches; 18.3 per cent. of the whole number were between 62 and 63 inches, and one half of them were within about 1½ inches of the average, the probable error. The ordinates or vertical lines are pro-

* 'American Titles and Distinctions,' W. Le Conte Stevens, THE POPULAR SCIENCE MONTHLY, **63**: 312–320, 1903. 'The Education of Examiners,' E. B. Sargent, *Nature*, **70**: 63–65, 1904.

† Many instructors doubtless let the grade represent the percentage of questions correctly answered. This is a possible but fallacious method in a subject such as mathematics; in a subject such as psychology it is impossible.

portional to the number of women falling within the limits of an inch. Thus 16.3 per cent. were between 63 and 64 inches; 11.5 per cent. between 64 and 65 inches, etc., only two falling between 70 and 71 inches. The women near the average tend to differ in height by about 1/200th of an inch, while the tallest or shortest of the thousand tend to differ by half an inch or more. This curve, showing the

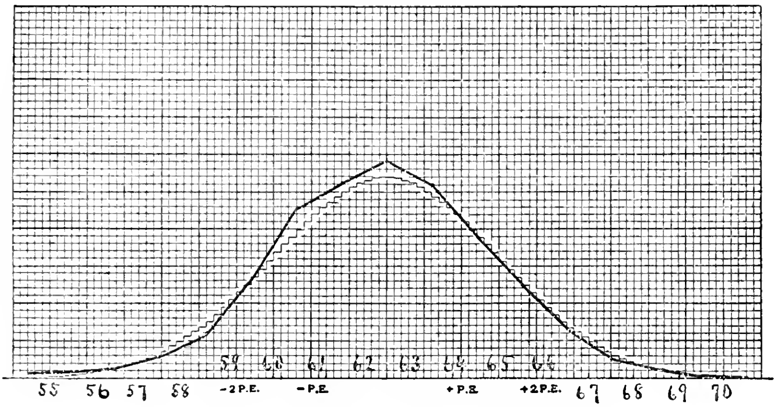


FIG. 1. DISTRIBUTION OF STATURE OF WOMEN IN INCHES.

distribution in height, corresponds closely with the fainter and more regular curve on the figure which represents the distribution of events due to a large number of small causes equally likely to affect them in one of two ways, the curve of error of the exponential equation whose properties have been discussed by Gauss, Laplace and other mathematicians.

If the performances of students in examinations are assumed to vary in the same way as their height, then we can if we like place them in classes which represent equal differences. Thus by the Harvard-Columbia method of grouping into five classes, if we put half the men into the middle class, C, and let B and D represent an equal range, we should give about 23 per cent. of both B's and D's and about 2 per cent. of both A's and F's. This, however, gives too few men in the A and F classes for our purposes. If we make the range of the unit 20 per cent. smaller, we obtain the distribution shown in Figure 3, according to which of ten men four would receive C, two B, two D, one A and one F. It departs slightly from the theoretical distribution, but certainly not so much as the theoretical distribution departs from the actual distribution. It appears to be the most convenient classification when five grades are used; one in ten being given honors and one in ten being required to repeat the course corresponding fairly well with the average practise and being a convenient standard.

It is maintained by Dr. Galton, Professor Pearson and others that ability and performance are distributed in accordance with the curve of error. It does not seem to me that this is the case. If ability for scholastic work were distributed in this way at birth, it would not remain so among college students, who are a selected group. Those unfit are less likely to be found in college and those particularly competent are more likely to be there. This would tend to give us for college students a skew curve in the negative direction. In spite of this factor, I believe that the main skew is in the opposite direction,

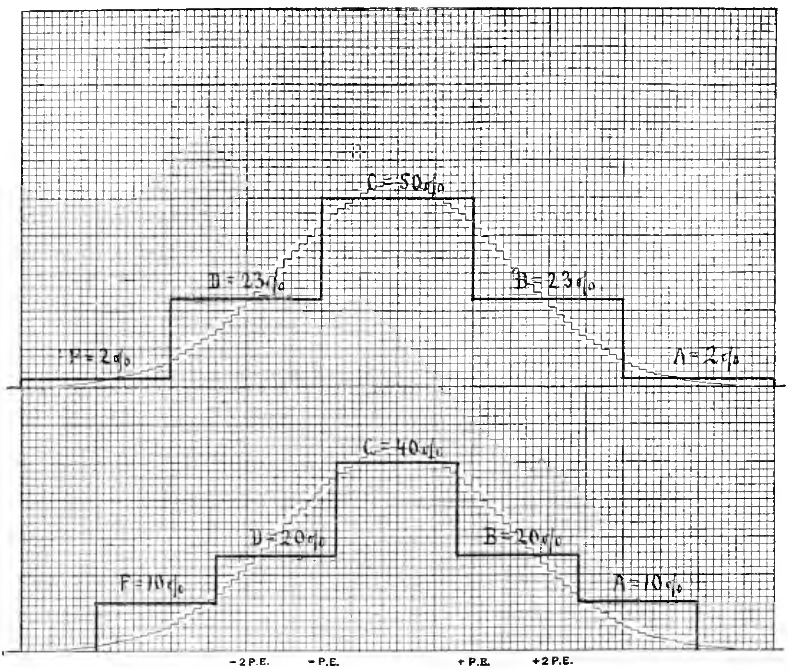


FIG. 2. THE UPPER SURFACE SHOWS THE THEORETICAL DISTRIBUTION OF GRADES, THE LOWER THAT MOST CONVENIENT IN PRACTISE.

and that ability is distributed somewhat like wages which are roughly proportional to it. If the average earnings of men in this country are $600 a year, it is clear that the positive deviations from the average are many times the negative deviations. There may be a certain minimal ability necessary for survival, and variations and sports may occur to an extent in the positive direction not possible in the negative direction. There are certain 'constant errors,' such as a college education, which divide men into different 'species.' In so far as students are graded on the lines of the probability curve, this may measure the attitude of the examiner rather than the distribution of the men in merit.

But we do not need theorizing so much as facts, which should be secured without delay. In the papers quoted above I have shown that it is possible to transform a qualitative series into one giving measures of differences. If the same thousand examination papers were read and graded independently by ten examiners, the variation in the grades of the same paper by different examiners would give us a measure of the differences between the papers, which would be inversely as the variation of the grades. I have in this way made a curve for the distribution of scientific performance in a selected group, and the same methods should be applied to merit in examinations.

In the meanwhile I am able to give the grades actually assigned in several cases. The accompanying table shows the grades given to 200 students in each of five courses in Columbia College, and the figure shows the averages and the grades in English A and Mathematics A. The average grade is a little above C, the median grade

PERCENTAGE OF STUDENTS RECEIVING

	A	B	C	D	F
Eng. A	4.5%	41.5%	44.5%	4.5%	5%
Eng. B	4	40	39	6.5	10.5
Math. A	11	24	24	22	19
Hist. A	10.5	28	28.5	20	13
Econ. A	9	36	33	17.5	4.5
Average	8	33.9	33.8	14.1	10.4

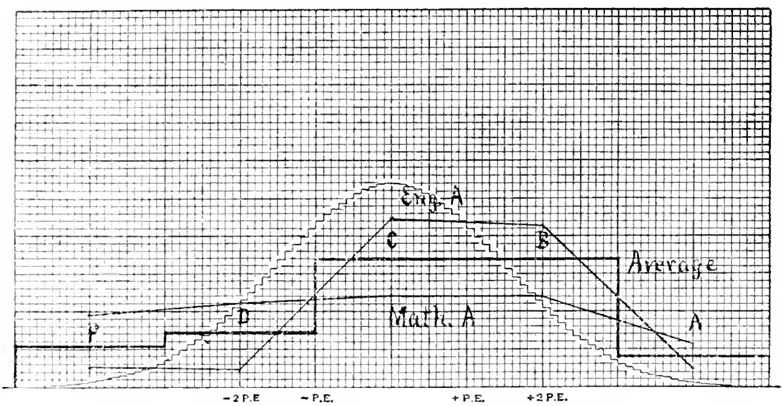


FIG. 3. THE DISTRIBUTION OF THE AVERAGE GRADES ASSIGNED IN FIVE COURSES, WITH THE DETAILS FOR INTRODUCTORY COURSES IN ENGLISH AND MATHEMATICS.

is nearly midway between C and B, and more than two thirds of all the grades are either C or B. Eight per cent. of the grades are A and ten per cent. are F, which approximates closely to the standard recommended above. The average of the grades assigned in these courses does not vary considerably, but the distribution is different. In the courses in English the distribution tends to follow the normal

curve of error, with the failures as a separate group or species. In the courses in mathematics and history the groups are more nearly equal in size, except in the case of 'excellent.' Here the range of ability is presumably greater in D and F than in B and C. The distribution in economics is intermediate. The fact that the courses in English, though given by different instructors, correspond closely shows that within a department certain standards may be followed; and this would be possible for the whole college or for the educational system of the country. It is only necessary to adopt the standards and then to teach people how to apply them.

I have also counted up the average grades assigned to 200 students in their first ten courses. In the table and curve, A represents the range between A and B + ½, B the range to C + ½, etc. Here

Average grade	A	B	C	D	F
Per cent. of students	2.5	34	46.5	16.5	0.5

the grades tend to be bunched, the differences between the men being partly obliterated by the combination of the grades in different courses.

In the next table and in the figure are given the grades of 15,-275 papers assigned by the examiners of the College Entrance Ex-

Rating	100–90	89–75	74–60	59–50	49–40	39–0
Per cent. of papers	6.1	21.4	32.6	12.1	11.1	16.7

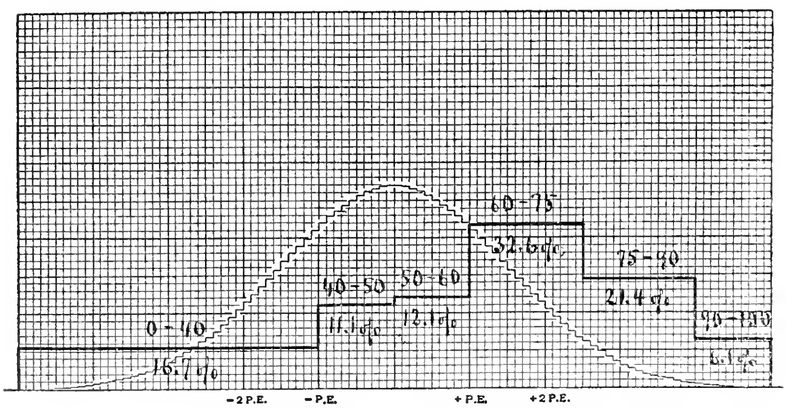


FIG. 4. DISTRIBUTION OF GRADES OF THE COLLEGE ENTRANCE EXAMINATION BOARD.

amination Board in 1904. The grades are in this case given on a centile scale. The curve is decidedly skewed in the negative direction, the most frequent grades being between 60 and 75. There is a considerable variation in the different subjects. Thus 10.6 per cent. of the candidates are given a grade above 90 in Greek and only 2.7

per cent. in history; 34.9 per cent. are given a grade below 50 in mathematics and only 19.1 per cent. in English. It is obvious that such grades should be standardized. It may be remarked incidentally that it is easy to select examiners by a competitive examination. If twenty candidates grade the same sets of papers, those whose grades are nearest the average of all the grades are likely to be the most competent examiners.

In these cases, and in all grades with which I am acquainted, there is a tendency to grade students above the average. Professor Pearson finds that in estimating the health of English boys, teachers place twice as many above 'normally healthy' as below, and he seems to regard it as gratifying that English boys should be more than normally healthy. We look on our own students as better than the average and in any case give them the benefit of the doubt. We call things 'fair' that are only average, and then the word 'fair' comes to mean average. Then we assign the grade 'fair' to students who are below the average, and a 'fair' student comes to mean a poor student. In assigning grades such words should be avoided; we should learn to think in terms of the average and probable error.

If grades are given on a centile system, the grade should mean the position of the man in his group; thus 60 should mean that in the long run it is more likely than anything else that there would be forty men better and fifty-nine not so good. The average probable error should be determined and a probable error should be attached to the grades; thus the grade 60 ± 10 means that the chances are even that there are between thirty and fifty men in the group who are better. The probable error becomes smaller as we depart from the average man; I estimate on the basis of a few experiments that it is over 10 in the middle of the scale. If this proves to be correct on the basis of more extended data, it is needless to grade more closely than on a scale of 10, though the first decimal would have some meaning when the grades are combined. If a hundred men are divided into ten groups of 10 each, the men in the middle groups will differ less from each other than those towards the ends, and if we wish to let the groups represent approximately equal ranges of merit, we can, as explained above, make five groups, A, B, C, D and F, putting 40 men in C, 20 men in both B and D and 10 in both A and F.

The determination of the validity of the grades given to college students and their standardization appear to me to be important because I regard it as desirable that students should be credited for the work they do rather than for the number of hours that they attend courses. By our present method a student who fails gets no credit at all, while a student who is nearly as bad (and perhaps worse)

gets as much credit towards his degree as the best student in the class. In our graduate faculties we credit men for work they do, and this principle is also adopted in the secondary schools that have broken the 'lock step.' Just now we hear much about the need of shortening the four year college course. Men can not do the work of four years in three by attending more courses each year, but some men accomplish as much in three years as others do in four, and many men, if they had an adequate motive, would do as much in three years as they now do in four.

We find among our graduate students that the better men can obtain the doctor's degree in about half the time required by the poorer men, while in exceptional cases the range is greater. I have found in various fundamental traits that can be measured, such as accuracy of perception, reaction-time and memory, that ordinary individuals differ about as 2:1. It seems that the best men (say the first ten) in our classes differ from the poorest (say the last ten) in about this ratio. If, therefore, men are divided into five groups representing nearly equal ranges of ability and we give the C, or middle group, a credit of three points for a three hour course, it would be just to give the A group 4 points, the B group 3½ points, the D group 2½ points, and the F group 2 points or less.

In Columbia College sixty points are required for the bachelor's degree, a point being an hour's attendance at lectures or recitations, or two hours of laboratory work. Students are expected to attend classes for about 15 hours a week and usually receive the degree in four years; there are, however, some who attend 20 hours a week and receive the degree in three years. At Harvard College 54 points are required, and I understand that about half the students now accomplish the work in three years. When 60 points are required for the degree, and if credits as proposed above were assigned, the 200 students of Columbia College whose grades have been compiled on the basis of half the work for the degree would be required to attend a total number of hours, as follows:

Grades	A	B	C	D	F
Per cent. of students	2.5	34	46.5	16.5	0.5
Hours for degree	40–45	45–55	55–65	65–75	75 +

This would be a just assignment of credits to the best of our present knowledge. It would permit about one third of the best students to secure the degree by an attendance of from 15 to 18 hours a week for three years. If, however, it is thought that this gives too great a reward for good work and too great a penalty for deficiency, the credits and deductions could be halved. This would give for these students an attendance, as follows:

Grades	A	B	C	D	F
Per cent. of students	2.5	34.5	46.5	16.5	0.5
Hours for degrees	47.5–52.5	52.5–57.5	57.5–62.5	65.5–67.5	67.5 +

Or, if the grades were standardized on the lines here proposed, the percentages would become:

Grades	A	B	C	D	F
Per cent. of students	10	20	40	20	10
Hours for degree	47.5–52.5	·52.5–57.5	57.5–62.5	62.5–67.5	no degree

It would also be possible to introduce the principle of giving extra credit for good work in a less radical manner, for example, by allowing a credit of three points to students who receive the highest grade in at least five courses. The application of the principle in any form would be an important educational advance, but a method such as this would not be nearly so fair and accurate as the plan here recommended. It would affect only a few men and would be more dependent on chance. The amount of credit in the plan recommended can be so adjusted that a given percentage of students can receive any credit desired: those receiving the highest grade (the first ten per cent. in the long run) could be awarded, on the average, an extra credit of 2, 3, 5, 10 or 20 points, as may be decided, and all others would receive credits in proportion.

I see no serious objection to the plan. The aberrancy of grades in different subjects would be a drawback, but not so serious as the existence of 'snap courses' under the present system. The adoption of the plan would tend to the standardization of grades, and the apparent objection might prove to be a real advantage. If it is objected that it would lead students to work too much for grades, this would simply mean, if grades are properly assigned, that it would lead them to do better work. The present method, where the grade is simply a kind of prize or punishment putting one man before another, seems to have objections; I have some sympathy with the students who call 'C' the 'gentleman's grade.' But if grades had some real meaning, they would be no more invidious than the payment of a salary of $3,000 to one man and of $5,000 to another. If it is said that the method is unfair because grades can not be given in accordance with exact deserts, it may be replied that this is true of all salaries and the like. Although a single grade is subject to a considerable probable error, the error of the average of a number of grades decreases as the square root of the number. Thus, if the probable error of a single grade is one place (that is, if a man receives C, the chances are even that he deserves a higher or a lower grade), the average of 25 grades (about the number of college courses taken for the degree) would be subject to a probable error of only one fifth of a place. Lastly it may be

said that the bookkeeping is very simple—the credits for 400 students can be compiled by an ordinary clerk in one day.

The assignment of credits in accordance with the work done by the student rather than for the number of exercises he attends appears to be in accord with common sense and justice. If after four years' study one man has the qualifications for the B.A. and another for the M.A., each should be given his appropriate degree. It may be well for one student to attend exercises for twelve hours a week and for another to be eighteen hours in attendance, but if each accomplishes the same amount of work they should be given the same credit. The plan would prove an excellent stimulus to good work and would attract to the college that adopted it the best class of students.

I should myself not only like to give students credit for the degree in accordance with the work they do, but I should also like to see tuition fees charged in proportion. In this case conduct and character should be included as well as merit in class work. More of the endowment of the institution should be used for those whose education is the greater service to the community, while those whose presence in a college interferes with its work should not be supported at the public expense. If the tuition fee is $150, it should be apportioned as follows:

Grades	A	B	C	D	F
Per cent. of students	10	20	40	20	10
Tuition fee	$100–120	$120–140	$140–160	$160–180	$180–200

But I fear that it will be even more difficult to convince trustees than faculties that psychology is becoming an exact science.

SHORTER ARTICLES AND DISCUSSION.

DE MORGAN AND CHARACTERISTIC CURVES OF COMPOSITION.

To the Editor: In his quotation from Augustus De Morgan in reference to the application of the law of averages to the detection of authorship and in his remarks thereon (see the December number of this journal) Dr. Raymond Pearl is, unconsciously of course, guilty of the exact fault which he, by implication at least, attributes to others; namely, ignorance of the work of previous writers upon the same subject. As his note seems to invite others to share with him in that ignorance, it may be desirable to explain, *once more*, that it was this very suggestion of De Morgan's that started the investigation of more than twenty years ago; that in the presentation of the first results to the American Association for the Advancement of Science, De Morgan was fully credited with the idea; in the publication of these results in Science (about 1885) indebtedness to De Morgan was distinctly acknowledged; also in subsequent publications and papers, the latest being an article in a recent number of this journal (August, 1904);—all of which can easily be seen and known by anybody who cares enough about the subject to look it up. In the first, and, as far as I know, the only thorough test of De Morgan's idea, made more than twenty years ago, it was found to be difficult, perhaps impossible, to discriminate among authors by means of simple 'Average word lengths,' as suggested by De Morgan. The scheme for the graphic display of the variations in the average frequency of occurrence of words of different lengths was then devised, proving to be a vastly more powerful means of revealing peculiarities of composition. This is the only feature of the work which has been claimed as original, and the results of an exhaustive application of it were published in 1901, confirming me in my confidence in the truth of the general principle stated by De Morgan, though not in the value of the specific application of it suggested by him.

I believe that the scheme of analysis by 'Characteristic Curves,' devised a quarter of a century ago, has been 'rediscovered' one or twice since; but it should never be overlooked that the germ of the thing was in a brief remark that I found in that now, but never-ought-to-be-out-of-print book, the 'Budget of Paradoxes.' The 'Memoir' from which the letter is quoted by Dr. Pearl did not appear until many years later. As I now remember it, the original suggestion was much less elaborated than in the letter, which I think I have never seen before.

I do not understand why Dr. Pearl calls this the 'Sherman Principle.'

T. C. M.

Rome, Italy,
December 17, 1904.

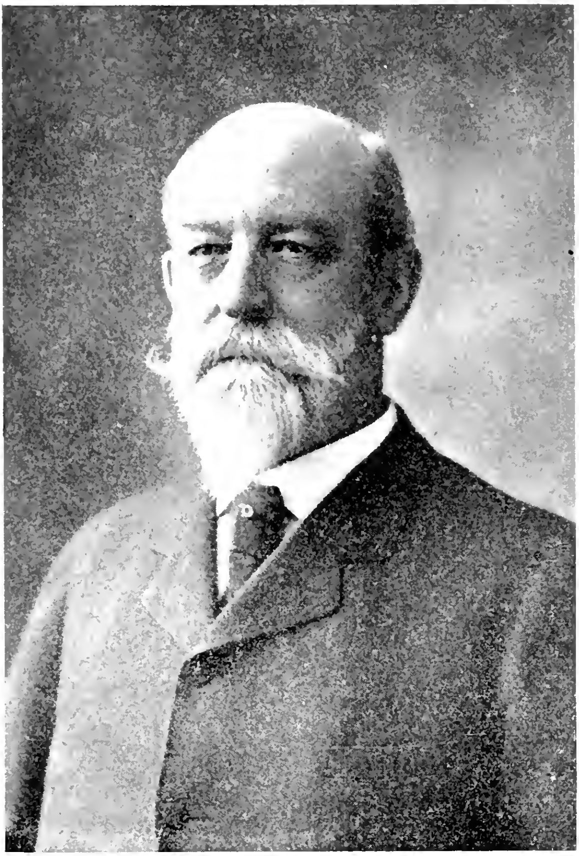
THE PROGRESS OF SCIENCE.

CONVOCATION WEEK IN PHILADELPHIA.

The American Association for the Advancement of Science has been fortunate in its associations with Philadelphia. In our last issue we called attention to the fact that its first meeting was held there in 1848, and it was there again in 1884 that the registered attendance reached its maximum of 1,261, including 303 representatives of the British Association. If we include the members of societies which met in affiliation with the association at the third Philadelphia meeting, held during convocation week in December, the number of scientific men in attendance must be estimated as about 1,200, although only 581 members registered under the several sections of the association. Perhaps there has never been a larger gathering of American workers in science. More significant than mere numbers is the representative character of the men in attendance, the spirit of the convocation as a whole and its influence upon the general public. In all these respects the recent meetings at Philadelphia were eminently successful. There were, in addition to the nine sections of the association which were in session, thirty affiliated societies and scientific clubs, including a majority of the national societies in the exact and natural sciences. More than 500 papers were read, covering even a wider range of topics than the names of the societies would indicate.

The societies were comfortably accommodated in the beautiful buildings of the University of Pennsylvania, many of which were independent objects of interest to visiting members. The material conveniences were but typical of the hospitality which the several societies enjoyed at the hands of the provost, vice-provost and faculty of the university and the local committee. A feature in the entertainment of guests was the lunch provided daily for all in attendance. There were the usual receptions, smokers, etc., and excursions to many places of interest to all scientific men or to special groups, including such important local institutions as the Baldwin Locomotive Works, Cramp's Ship Yard, the United States Mint and the Navy Yard.

The number and variety of papers of popular interest was notable, including discussions of some of the most promising applications of science in invention and industry, in agriculture, in medicine and in social economics. All the societies were fortunate in that the American Association had secured the services of Mr. Theodore Waters, as press secretary, in order to insure more adequate reporting of the meetings than has been possible hitherto. This is an important consideration, as it is assuredly one of the purposes of the association to impress upon the general public the dignity and importance of science. Modern civilization is increasingly dependent on the progress of science, and men of science must profit by the sympathy and support of the public benefiting by their labors. Owing partly to geographical conditions, partly to inadequate organization, though doubtless not wholly to these causes, there is here less public interest and general participation in the annual meetings of the American Association than is the case in England with regard to the British Association. It is evident, however, that our public inter-



H. P. BOWDITCH,

Professor of Physiology, Harvard Medical School, Vice-President for Physiology and Experimental Medicine.

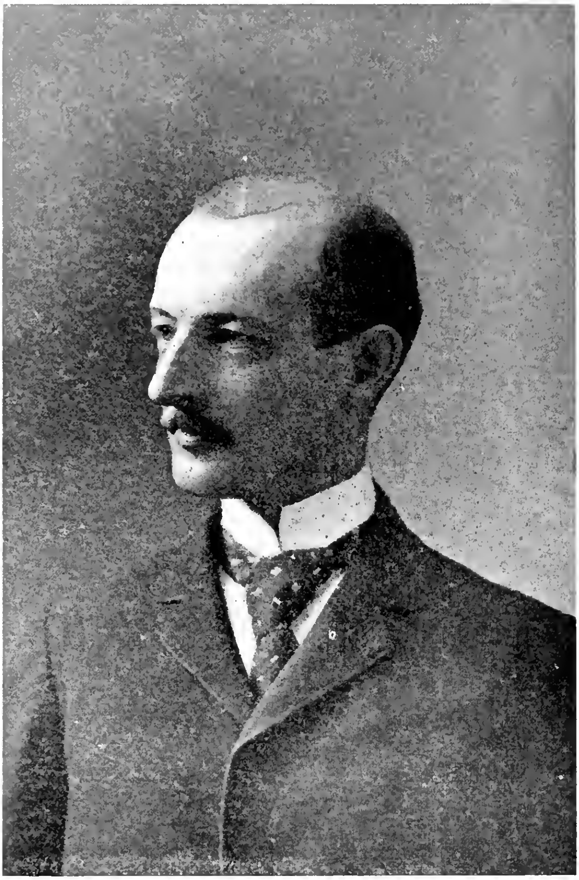
est not only comes short of what it should be, in view of the real importance of science in our life and the possible value of the association to the nation, but it at present comes far short of what it is destined to become, we venture to hope, in the not distant future. All sympathizers with science, that is, all intelligent sympathizers with civilization, should be enrolled as members of the association. The present membership of about 4,000 should be speedily doubled, if not tripled, if the association is to do the work for which it is fitted. Its growth has been steady, but not commensurate with the growing needs of American science. Since the last meeting 377 new members have been added. Especially desirable is it that all scientific workers be members of the association as well as of their respective technical societies. It may not be generally known that any scientific society so desiring may, by vote of the council, become affiliated with the central association, without in the least sacrificing its autonomy, thereby gaining not only the advantage of profiting by the arrangements for the meetings which the association undertakes, but securing representation in the counicil in proportion to the number of its members enrolled as fellows of the association.

LEONARD P. KINNICUTT,

Professor of Chemistry, Worcester Polytechnic Institute, Vice-President for Chemistry.

THE AMERICAN ASSOCIATION.

The fifty-fourth meeting of the American Association was presided over by Professor William G. Farlow, the eminent botanist of Harvard University, who responded to the address of welcome tendered by Provost Harrison of the University of Pennsylvania. We are pleased that we are able to give here portraits of the vice-presidents who presided over the sections and of the permanent secretary and the secretary of the council. No report of the sectional meetings can be attempted, and only a brief account of the more important business proceedings. In some respects this is a critical period in the development of the association. With the increasing specialization of methods and of the sciences, a number of special societies of experts have arisen, which tend to replace, in a way, the older and more general association. Just what relation the latter should bear to the several societies affiliated with it is an important question of policy awaiting early solution. It is thought by some that the association should aim to serve as a central legislative body and to coordinate and represent to the public at large the common interests of the several special bodies, while yielding to these the sessions for the reading of technical papers. The Philadelphia convocation was notable



David S. Jacobus,

Professor of Experimental Mechanics and Engineering Physics, Stevens Institute of Technology, Vice-President for Mechanical Science and Engineering.

for the harmony which prevailed between the special societies and the general association. In several cases the sections had charge of a general session in one half the day, and the affiliated societies of a meeting during the other half. Those sections of the association with which affiliated societies met were naturally the most largely attended. In regard to other questions, such as time and place of meeting, a certain amount of conflict of interests is bound to occur. It may be desirable and feasible for the association to hold two meetings annually, one during convocation week, primarily in the interests of scientific organization in America, another in the summer, somewhat more along the old lines familiar to our readers. These and other vexing questions of policy come up at Philadelphia, and were reported on by the committee on the policy of the association. This committee was empowered to exercise a general executive control of the preliminary arrangements for meetings and of the publications, and President R. S. Woodward, of the Carnegie Institution, was appointed as its permanent chairman, continuity and responsibility being thus insured.

The national character of the asso-

WM. F. MAGIE,

Professor of Physics, Princeton University, Vice-President for Physics.

ciation was emphasized by the selection of New Orleans as the place of meeting during next convocation week, beginning on December 29, 1905. Boston was recommended as the place of meeting for 1906. It was also recommended that a summer meeting be held in Ithaca in 1906. Professor Calvin Milton Woodward, of Washington University, St. Louis, was elected president of the association for the New Orleans meeting. Professor Woodward was born at Fitchburg, Mass., August 25, 1837. He is a graduate of Harvard (1860) and a doctor of philosophy from Washington University (1883). He has occupied the chair of mathematics and applied mechanics at the Washington University since 1870, and for many years he served as dean of the school of engineering. In 1879 he originated the St. Louis Manual Training School, of which he has been director ever since. Dr. Woodward has been an active member of the St. Louis school board and the president of the board of regents of the Missouri State University. He has written important books on manual training in education. A member of the association since 1883, he has been interested in the work of three of its sections, those of mathematics and astronomy, of mechanical science and engineering, and

B. L. ROBINSON,

Asa Gray Professor of Systematic Botany, Harvard University, Vice-President for Botany.

of social and economic science, having been secretary for the last two, and at different times elected to the vice-presidency of the same. At Philadelphia he gave the vice-presidential address before Section D on 'Lines of Progress in Engineering.' His portrait will be found in the issue of the MONTHLY for February, 1904. Space does not permit more than a list of the well-known names of the newly elected vice-presidents, which are as follows:

Section of Mathematics and Astronomy—Professor W. S. Eichelberger, Washington, D. C.

Section of Physics—Professor Henry Crew, Evanston, Ill.

Section of Chemistry—Professor Charles F. Mabery, Cleveland, Ohio.

Section of Mechanical Science and Engineering.—Professor F. W. McNair, Houghton, Mich.

Section of Geology.—Professor William North Rice, Middletown, Conn.

Section of Zoology.—Professor H. B. Ward, Lincoln, Nebr.

Section of Botany.—Dr. Erwin F. Smith, Washington, D. C.

Section of Anthropology.—Dr. George Grant McCurdy, New Haven, Conn.

Section of Social and Economic Science.—Professor Irving Fischer, New Haven, Conn.

Section of Physiology and Experimental Medicine.—Professor William T. Sedgwick, Boston, Mass.

C. Hart Merriam,
Chief of the U. S. Biological Survey, Vice-President for Zoölogy.

Dr. L. O Howard, of Washington, D. C., was reelected for a term of five years, as permanent secretary; Profeessor C. A. Waldo, of Lafayette, Ind., as general secretary and Professor John F. Hayford, of Washington, D. C., as secretary of the council.

THE PRESIDENTIAL ADDRESS.

The address of the retiring president, Dr. Carroll D. Wright, formerly U. S. Commissioner of Labor, now president of Clark College, was an event of unusual significance. Dr. Wright, as is well known, is an economist, and he chose for his subject 'Science and Economics.' After referring to the revolutionizing influence of science in the realm of theology and religion, President Wright pointed out a similar influence, not as yet generally appreciated, in the sphere of political economy. The subject was, properly, presented in broad, general outlines, touching as it does a wide range of topics, such as the Malthusian theory of population, the law of diminishing returns, the iron law of wages, and the like, and even the tariff, together with such matters as the relation of chemistry and engineering science to problems of national and international politics, and the

EUGENE A. SMITH,
State Geologist of Alabama and Professor of Geology in the University of Alabama,
Vice-President for Geology and Geography.

physiological and psychological conditions of efficiency as factors in the labor problem. It was shown how the progress of science has resulted in the abandonment or modification of the hard and fast theories of the classic school of political economists and the substitution of more flexible formulas, suited to the number and variety of facts brought to light by newer methods of investigation not only in economic and social science, but in the so-called exact and natural sciences as well. Modifications of old 'laws' also become necessary as the result of the progress of applied science, the extensive use of machinery, *e. g.*, tending to modify the operation of the 'law of diminishing returns.' Agricultural science, or more accurately, the agricultural sciences, stand in the closest relation to the economic situation in any civilized country, and consequently not only to the science of economics, but to governmental policy.

President Wright's address was typical of the interests and objects for which the association exists. THE POPULAR SCIENCE MONTHLY has consistently maintained that science is not a thing apart, the curious pastime of an exclusive clique, but that it is nothing more nor less than the most complete and exact statement of fact that can be reached by the most careful and thorough methods of inquiry, and that

WALTER HOUGH,
Assistant Curator, Division of Ethnology, U. S. National Museum, Vice-President for Anthropology.

its results belong not to the few, but to the many, apply not in the domain of industry and our material civilization alone, but over the whole range of life's activities, are not for individual advantage chiefly, but for the public good. When society in general and governments in particular appreciate the true source and guardian of their highest welfare, then many things now desired, and many more no less needful, will be possible of attainment. It does not follow that because nations have for the most part stumbled along through a process of trial and error without planning their trials or measuring the significance of their errors, that they will always entail such waste in a needlessly blind pursuit of progress. The world proceeds by gradual evolution, yet, as we have often insisted and again repeat, this time in the words of Mr. John Morley, 'evolution is not a force, but a process; not a cause, but a law.' Ideas may be forces, purposes may be causes, and intelligent cooperation and organized effort may minister to the economy of social progress as they have to the promotion of success in the whole world of private business. The like principle holds for the internal organization of scientific men and scientific bodies themselves. There must be a solidarity of sympathy and aims among scientific workers if total efficiency, and not merely partial efficiency here and there, is their aim. When the forces of

MARTIN A. KNAPP,

Chairman of the Interstate Commerce Commission, Vice-President for Social and Economic Science.

science shall have become satisfactorily organized within, then it will be possible for science as a whole to take its proper place in public affairs.

THE AFFILIATED SOCIETIES.

Among the important societies which met with the association were the American Chemical Society, under President Arthur A. Noyes; the American Physical Society, with President Arthur A. Webster in the chair; the Astronomical and Astrophysical Society of America, presided over by Professor Simon Newcomb; the Geological Society of America under President John C. Branner; the newly organized American Geographers' Association, Professor W. M. Davis presiding; and the American Society of Naturalists with its several affiliated societies, including those devoted to botany, zoology, anatomy, physiology, bacteriology, anthropology, psychology, philosophy, etc. Notable too was the interest shown in the vigorous societies devoted to the application of science, in agriculture, horticulture, entomology and other lines. The meeting of the American Chemical Society, the first to affiliate with the association, was particularly successful, 240 chemists having registered. It was necessary to subdivide into smaller sub-

CHARLES S. HOWE,

President of the Case School of Applied Science, Cleveland, Ohio; General Secretary o the American Association.

sections for the reading and discussion of the sixty odd papers that were presented. Under the auspices of the Naturalists, Professor Henry Fairfield Osborn gave an interesting illustrated lecture in the lecture hall of the famous old Academy of Natural Sciences, his subject being 'Recent Discoveries of Extinct Animals in the Rocky Mountain Region, and their Bearings on Present Problems of Evolution.' 'The Mutation Theory of Organic Evolution' was discussed in a series of specially prepared papers by representatives of the most advanced research in their respective fields; plant breeding being represented by Dr. D. T. MacDougal, animal breeding by Professor W. E. Castle, cytology by Professor E. G. Conklin, paleontology by Professor W. B. Scott, anatomy by Professor Thomas Dwight, taxonomy by Professor Liberty H. Bailey and ethology by Dr. W. M. Wheeler. This was one of the best discussions that has been held before the Naturalists, as generally interesting as it was timely. It illustrates the value and need of comparison and coordination of the results of investigation in different fields for the solution of problems common to all. If methods are becoming more and more specialized with the growth of exactitude in the sciences,

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there is at the same time a growing class of problems which may be termed synthetic, to which special students must devote themselves without reference to the traditional boundaries of the separate sciences. These include the problems of evolution and many of the most pressing problems of solar research, geophysics, and the like, and still more of such applied sciences as medicine, agriculture and engineering. This suggests one of the strongest reasons, appealing to the interests of pure research itself, for a common meeting-ground of investigators in artificially separated though not unrelated fields, which shall serve as a clearing house for different classes of students at work on the same problems.

Professor William James, the eminent psychologist, who made a notable presidential address before the psychological association this year, was elected president of the American Society of Naturalists for the next meeting. There will inevitably be some separation of the societies next year, but it is hoped that all will be reunited for an especially good general meeting at Boston the year following.

SCIENTIFIC ITEMS.

The Nobel prize for physics has been awarded to Lord Rayleigh, professor of natural philosophy at the Royal Institution. The chemistry prize is conferred upon Sir William Ramsay, professor of chemistry at University College. M. Pavloff, professor at the Military Academy of Medicine at St. Petersburg, receives the prize for physiology and medicine. The literature prize is divided between M. Mistral, the Provençal poet, and Don Jose Echegaray, the Spanish dramatist. The peace prize has been awarded to the Institute of International Law.

Mr. Luther Burbank, whose important work on plant-breeding was described by President Jordan in the last issue of the Monthly, has been appointed a special lecturer at Stanford University. He has received a liberal grant from the Carnegie Institution, which will permit him to devote himself to scientific work—Professor Svante Arrhenius has been made head of a laboratory for physical chemistry, to be established at Stockholm by the Nobel Institute.—Dr. Horace Jayne has resigned the directorship of the Wistar Institute of the University of Pennsylvania.

Professor S. W. Burnham, astronomer at the Yerkes Observatory, has been awarded the Lalande gold medal of the French Academy of Sciences for his researches in astronomy.—The Lavoisier medal has been awarded to Sir James Dewar.—Professor G. Sergi has been made president for the International Congress of Psychology to be held at Rome from April 26 to 30 of the present year.—Lord Kelvin has accepted the nomination of the council for the presidency of the London Faraday Society, in succession to Sir Joseph Swan.

THE

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THE BERMUDA ISLANDS AND THE BERMUDA BIOLOGICAL STATION FOR RESEARCH.*

BY PROFESSOR EDWARD L. MARK,

DIRECTOR OF THE ZOOLOGICAL LABORATORY, HARVARD UNIVERSITY.

I FEEL a certain hesitancy in speaking on the subject I have selected to talk about—the Bermuda Islands—because of the number of prominent naturalists who have written so excellently about them. It should be stated at the outset that I do not aim to add to the stock of our knowledge about the Bermudas. So much has been written about their zoology in recent years—especially by the zoologists of the *Challenger* Expedition, then by Professor Heilprin of this city, on the invertebrates and the coral reefs, by Mr. Agassiz, incidental to his studies of the great question of the origin and growth of coral reefs, and most recently by that veteran in systematic zoology, Professor Verrill, of Yale University—that it is hardly to be expected that anything fundamentally new will be soon added. It is my purpose, rather, to give something of a picture of the present conditions in Bermuda, based partly on my own experiences, and particularly to direct your attention to the accessibility of the islands and their availability as a place for carrying on intensive rather than extensive researches. With the facilities for work which will soon be provided by the colonial government, it should be an attractive place not only for temporary exploration and summer study, but also for protracted investigations on important biological problems.

My own interest in Bermuda as a place for zoological study was first awakened by suggestions of President Eliot, who a few years ago

* A vice-presidential address prepared for Section F (Zoology) of the American Association for the Advancement of Science, at its Philadelphia meeting.

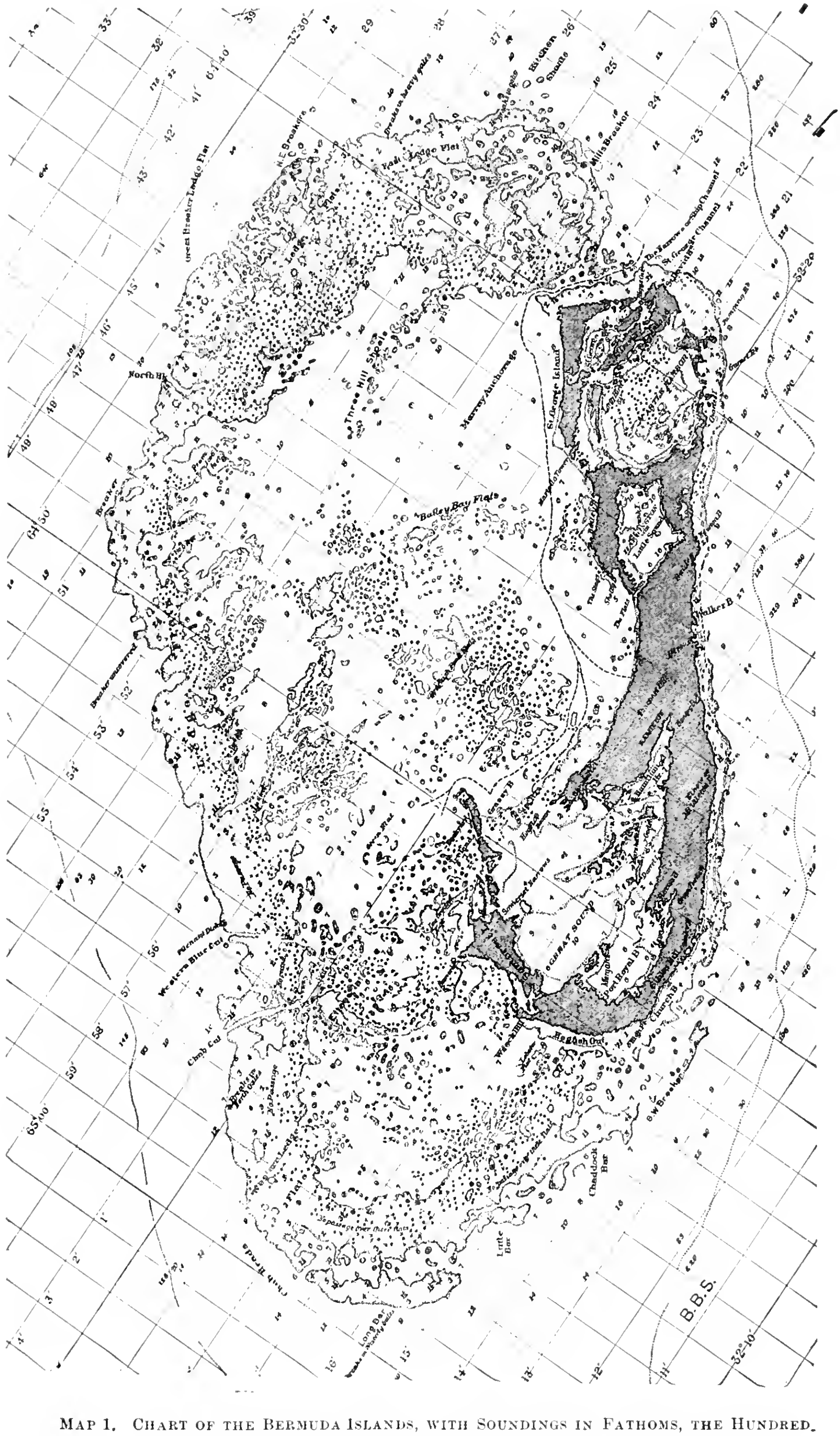
passed the winter in Bermuda, and upon his return inquired of me if I did not think it would be a good place for a marine laboratory. The more I inquired into the condition of living in the islands, and the marine organisms in the sea about the islands, the more I became convinced of the practicability of the place for a biological laboratory.

At the risk of saying much that is already familiar to many of you, I will give an account of some of the things which seem to me of interest in this connection.

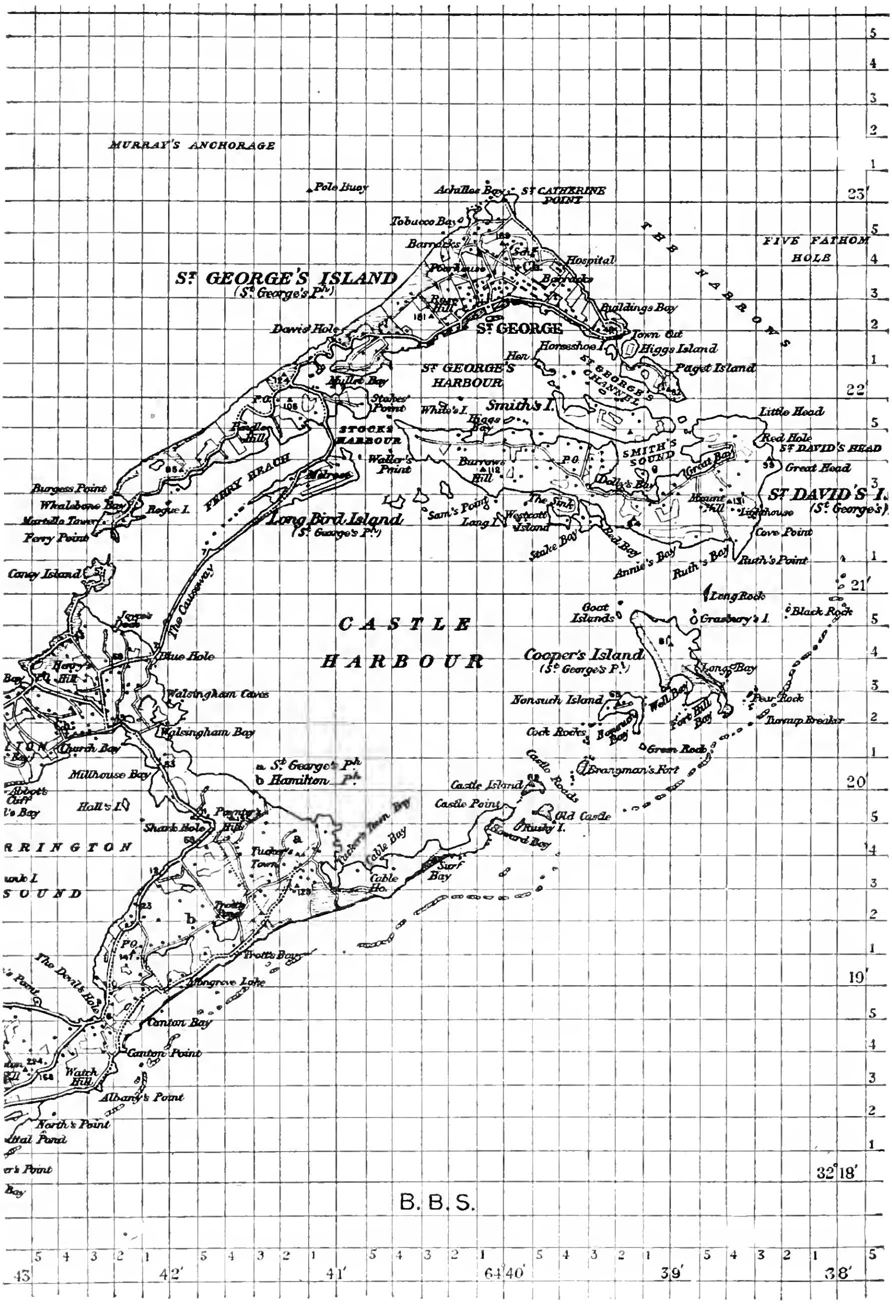
From fifty to sixty hours' steaming brings one from New York to Bermuda. It is worthy of note that the distance of the islands from New York or Boston is only about two thirds that of the Dry Tortugas or the Bahamas. The climate and the conditions of life in the Bermudas are safe and agreeable at all seasons of the year. Though the humidity is considerable, the temperature in summer rises to only 85° or 86° Fahrenheit; in winter it seldom gets below about 50°, and never to the freezing point. To the zoologist familiar with the animals of our north Atlantic coast and the water they live in, the waters that wash the shores of these islands and the brilliantly colored animals that inhabit them are a source of surprise and delight.

Leaving New York a little before noon on Saturday, the islands are usually sighted about mid-day on Monday, and landing is made in Hamilton a few hours later. If one has pictured to himself low-lying coral islands fringed with palm trees, he will be disappointed, and will be surprised to find that the land rises in many places to a considerable height—even to two hundred and fifty feet or more—and on approaching nearer to see, instead of palms, the dark green of the cedars that cover many of the hills. In passing from the deep waters of the Atlantic to the shallower depths near land, the dark blue of the ocean is replaced by livelier tints, in which greens predominate, and when the conditions of sun and sky are favorable, the variety of colors exhibited is truly wonderful. Even the far-famed Bay of Naples does not afford a more brilliant display of colors than is sometimes seen in the waters around the Bermudas.

In contrast with these fascinating, kaleidoscopic effects of the sea, the land presents either the dull gray appearance so common on the granite shores of New England, or the dark green of the cedars, which also reproduce the effect of the New England evergreens. If one could ignore the colors of the sea, he might easily imagine, as he steams along the northern shores of the Bermudas, that he was skirting some part of the Maine coast. One thing, however, would impress him as strange—the brilliant white specks and patches which here and there dot the hillsides or are clustered into larger or smaller groups—the limestone dwellings of the Bermudians. These with their white roofs, brilliant in the sunlight, are in marked contrast to anything seen on



MAP 1. CHART OF THE BERMUDA ISLANDS, WITH SOUNDINGS IN FATHOMS, THE HUNDRED-FATHOM LINE (DOTTED), THE SHIP CHANNEL (DASHES), AND THE LATITUDE AND LONGITUDE TO MINUTES.



MAP 2. NORTHEASTERN THIRD OF THE BERMUDA ISLANDS, WITH LATITUDE AND LONGITUDE LINES TEN SECONDS APART.

the Maine coast. Government House, on Mount Langton—the residence of the governor of the islands—is a conspicuous building on the crest of the ridge which hides the city of Hamilton from the approaching voyager.

After a long and rather circuitous course through the only channel available for steamers, and under the guns of several forts, one at length enters Hamilton Harbor between two rocks that are not far enough apart to allow the passage of two ships abreast. The still unfinished cathedral, two modern hotels for the accommodation of winter tourists, and the parliament house are the most conspicuous buildings in Hamilton, being situated on the highest part of the slope occupied by the town (Fig. 1).

The substantial city dock, with its low, unattractive sheds roofed in by arched and corrugated metal, extends along the whole water front.

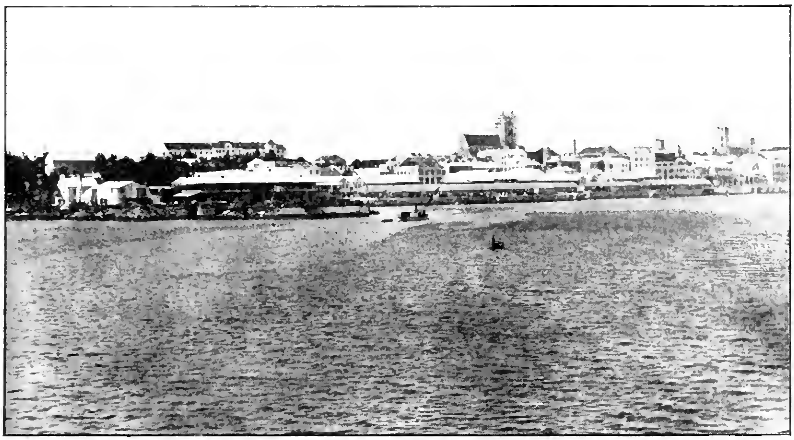


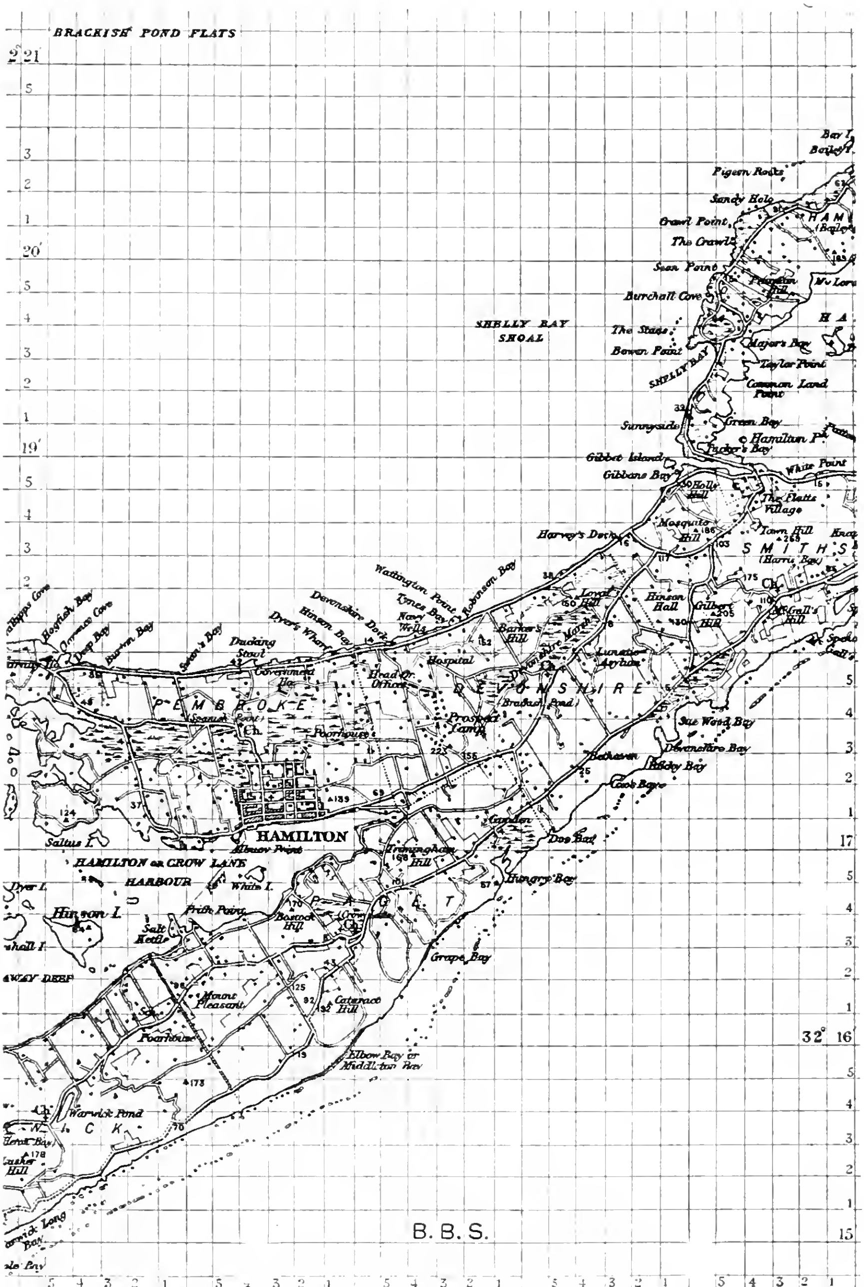
FIG. 1. VIEW OF HAMILTON FROM THE HARBOR. From a photograph by Phelps Gage.

Beyond the sheds runs Front Street (Fig. 2) parallel to the shore. Across the street from the sheds are the chief business houses of the town; some of them having a modern look, but the greater part of them with small windows and heavy solid wooden shutters that recall the northern country store of fifty or seventy-five years ago. Unlike the country store, however, the Bermuda store has a two-story portico extending out over the side-walk, so that the pedestrian is partly sheltered by it from the heat of the sun or the sudden down-pour of the unannounced shower that is so characteristic of the islands. The second story of this portico, like most of the dwellings (compare Fig. 3), is enclosed by shutters with immovable slats, which keep out heat and rain, but permit a free circulation of air within. The vehicles in the street range from the modern rubber-tired victoria to the low two-wheel cart drawn by horse, mule or ox.

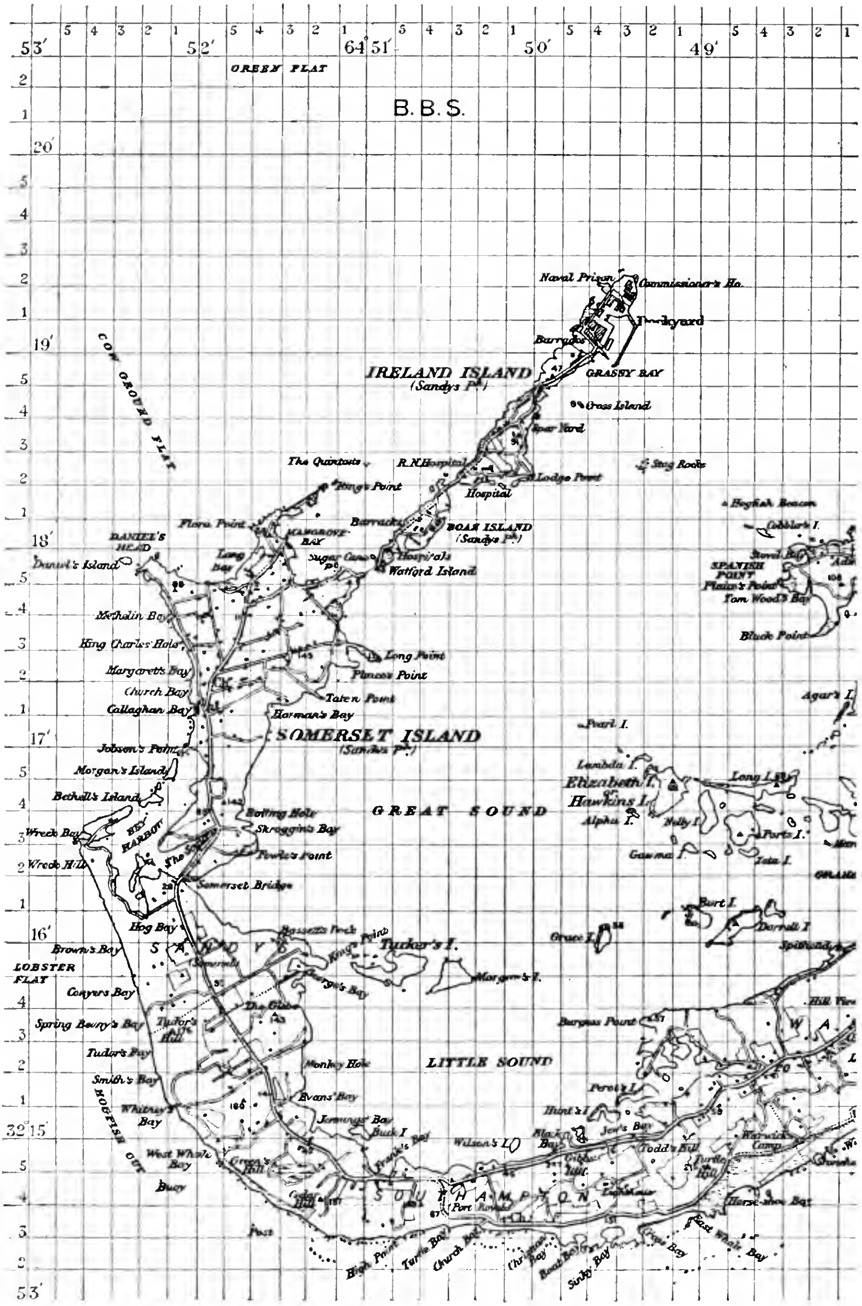
As a glance at the map will show (Map 1), the Bermudas consist of a chain of about half a dozen islands so grouped that the whole bears a fancied resemblance to a gauntlet. The broad wrist region at the northeast is made up of St. David's, Smith's and St. George's islands and a part of the main, or Bermuda, island, the rest of which stands for the hand, the thumb and the first joints of the fingers, the remaining joints of the fingers being represented by Somerset and Ireland islands. The whole length of the group from northeast to southwest is about fifteen miles, and the width is usually a mile or at most two miles; in many places it is much less. A fairly continuous ridge occupies the axis of the islands mentioned. Besides these larger islands, there are numerous smaller ones (Fig. 4), so that it may well be that there is, as claimed, an island for every day in the year. The larger islands are so indented by bays and sounds that it is evident they will

FIG. 2. FRONT ST., HAMILTON. U. S. CONSULATE IN THE DISTANCE. Photograph by L. J. Cole.

in time become divided up into smaller ones, and thus add to the existing number. The largest of the bodies of water on the north that seem to have eaten their way into the land masses is Castle Harbor (Map 2). This lagoon is from two to three miles in diameter, and communicates with the open sea on the southeast by several passages separating from each other as many small islands, and with a great northern lagoon by means of a long narrow arm of the sea called Ferry Reach. Connected with Ferry Reach at its northeasterly end is St. George's Harbor, which affords an excellent and well protected anchorage. Southwest from Castle Harbor, and separated from it by only a narrow ridge, is Harrington Sound, which looks like an inland lake (Fig. 5); it is a mile wide, two miles long, and in places sixty or seventy feet deep. This has but one communication with the sea above ground,



MAP 3. THE MIDDLE THIRD OF THE BERMUDA ISLANDS. THE POSITION OF THE LABORATORY IS INDICATED BY THE LINES '390' AT THE MARGINS OF THE MAP.



MAP 4. SOUTHWESTERN THIRD OF THE BERMUDA ISLANDS.

though there are several underground connections. This single surface-connection is by means of a passage only about thirty feet wide, through which the water rushes with great swiftness during every tide. It is surprising for how short a time at the turn of the tide, five or ten minutes only, the water is relatively quiet. This narrow passage leads directly to the Flatts Inlet, which in turn connects with the great north lagoon. The inlet, not being very broad, is therefore swept by a rather strong current. This region ('The Flatts,' Map 1) is of particular interest to us, for it is on this inlet that our laboratory is located.

All the waters held, as it were, in the hand of the fancied gauntlet —Great Sound, Little Sound (Map 4), Hamilton Harbor (Map 3),

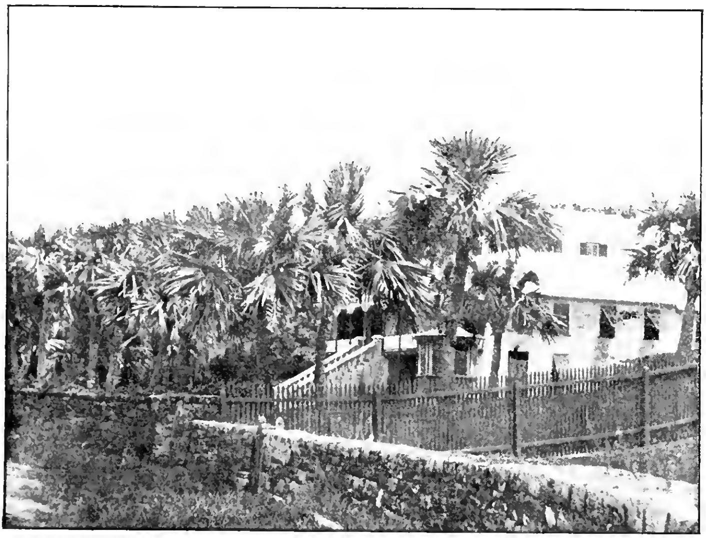


FIG. 3. RESIDENCE SURROUNDED BY PALMETTO TREES. Photograph by Phelps Gage.

etc.—form another extensive landlocked sea, which formerly, in all probability, communicated less freely with the north lagoon than at present, for a submarine ridge runs out from Spanish Point—the tip of the thumb (Map 1)—to Ireland Island. At several points this ridge is awash at low tide.

Through the greater part of the main island there are three parallel roads (Map 3): one—known as the middle road—runs in a general way along the ridge; the others—known as north and south roads—run along the north and south shores. The north and middle roads meet at The Flatts, and nearly all the travel between the only two cities, Hamilton and St. George's, passes over the bridge which crosses the gorge between the inlet and Harrington Sound.

The houses of Bermuda are, almost without exception, made of the

limestone rock which everywhere abounds. This is cut into blocks a foot or more in length, eight or ten inches wide and of different thick-

Fig. 4. Great Sound, looking South from Spanish Point.*

nesses. Even the roof is made of thin overlapping slabs of the same rock supported by slats that rest on wooden rafters. The houses, roof

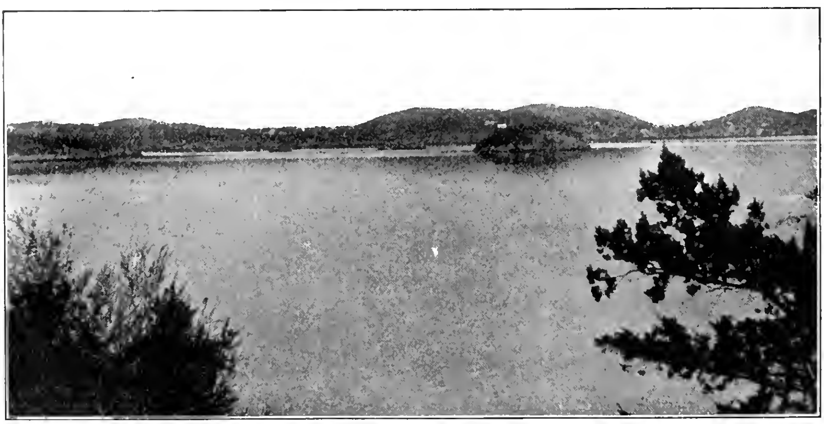


Fig. 5. Harrington Sound. Photograph by A. H. Verrill.

and wall, are whitewashed at frequent intervals, usually twice a year. The rain that falls on the roofs is carefully collected in covered cisterns, for it is the only source of fresh water in the islands, since

* I am greatly indebted to Professor A. E. Verrill for the use of about half of the figures, those which he has furnished having been taken from *The Transactions of the Connecticut Academy of Science* and from his 'The Bermuda Islands,' New Haven, 1902, and 'Zoology of the Bermudas,' New Haven, 1903.

there are no streams, and most of the rain pools last but a few hours even after the heaviest shower. In some localities barren tracts of land are denuded, the rock cut to a sloping surface and whitewashed to serve as a watershed for collecting rain water in larger quantity than the roofs supply.

In addition to the garrisons and the marines there are on the islands about 18,000 people, two thirds of whom are negroes, the rest whites, mostly of English extraction. There is a property qualification for voting; the proportion of whites to blacks on the voting list is two to one, the reverse of the ratio in population.

FIG. 6. ANCIENT STREET IN ST. GEORGE'S. Photograph by A. H. Verrill.

The cities, as I have said, are but two: the quaint town of St. George's and the more modern town of Hamilton. St. George's is the more interesting because of its tortuous narrow streets, its high garden walls and its ancient architecture, which suggest a medieval European town (Fig. 6). It was the seat of government until about a hundred years ago (1815), and retained for a long time after that an importance due largely to its fine harbor.

The visible land of Bermuda gives a very incomplete idea of the shape of the submarine plateau from which it rises. If the sea were to recede so that its surface was about thirty feet below its present level, we should have a great oval lagoon some twenty-five miles long and from twelve to fifteen wide, the rim of which would be made up in part of the present land area, and for the rest of a more or less continuous reef of coral-covered rocks a mile or so wide (Map 1). The great central basin—the great north lagoon, as I have called it—would have no considerable depth—seldom more than fifteen or twenty feet of water, and nowhere more than thirty—and would be studded with innumerable coral rocks and islands. Some of the deeper parts have special names, as Murray Anchorage and Grassy Bay, while the shallower parts are known as flats—Brackish Pond Flats, Bailey's Bay Flats, etc. The passages through this rim would be only three: Hogfish Cut, Chub Cut and the Narrows or Ship Channel. The slope of the sea bottom outside the rim is rather abrupt on the southeast side of the oval, less so on the northwest side, and least of all at the ends, as the position of the hundred fathom line shows. Beyond the hundred fathom line the bottom slopes even more rapidly to a depth of

1,200, 1,500 or even in places to 2,000 fathoms. These depths are reached at from two to five miles beyond the hundred fathom line.

Rising from the floor of the sea some ten or twelve miles to the southwest of this oval plateau is another much smaller one, which would still be some 150 or 200 feet under the surface were the sea to recede, as we have imagined, thirty feet. This is known as the Challenger Bank.

Ten miles beyond this is another similar plateau of about the same size and height, called the Argus Bank. These two banks are in reality a part—two detached peaks, as it were—of the great submarine mountain of which the Bermuda Islands are the visible summit. For

Fig. 7. Road Cutting near Hamilton.

while the floor of the ocean sinks within five miles to about 1,500 fathoms, these plateaus are separated from each other and from the Bermuda plateau by less than half that depth.

The present land area of all the Bermuda Islands is composed of calcareous rock which varies from a loose sand to a firm, hard, semi-crystalline limestone that resounds to the blow of the hammer. What underlies this, no one yet knows. The deepest excavations—those for the new Navy Yard docks at Ireland Island—have not disclosed any other kind of rock. The numerous deep cuts for roads (Fig. 7) and the quarries which are met with in all parts of the islands tell the same story. The rocks are composed of wind-blown calcareous sand. This sand, contrary to what was formerly supposed, is not composed of broken down corals. These are present only in small proportion, the

chief constituents being fragments of shells, serpula tubes and corallines. There are no such stratified subaqueous rocks as are found in this country, but everywhere the cut edges of the rocks show the peculiar sinuous lines that characterize the stratification of drifting sands. Most—if not all—of the harder rocks are doubtless the result of the action of water and air on these æolian masses. At almost every point where the action of the sea is traceable it has resulted either in cementing together the layers of these rocks till all evidence of stratification is

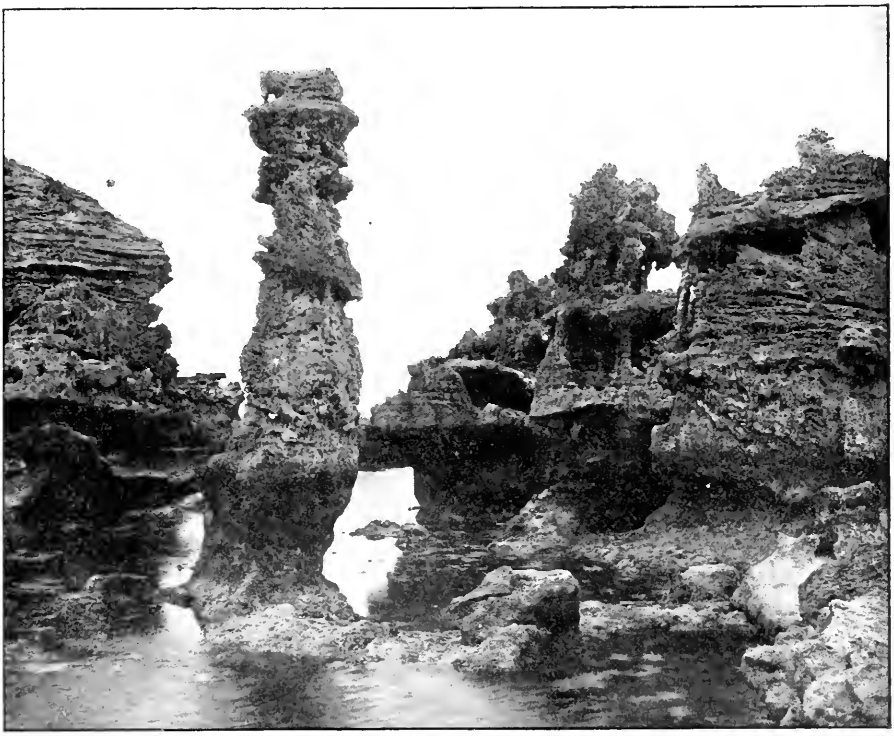


FIG. 8. WATER-WORN ROCKS, SOUTH SHORE.

lost, or else its mechanical effect has been more immediate than its chemical, and the rock has crumbled into its constituent grains and has become once more a sandy beach, in turn yielding up its substance to build the present sand dunes of the coast, which have the same æolian structure as their predecessors.

The mechanical action of the sea operating on the already hardened rocks has left them carved in the most fantastic shape (Figs. 8, 9), and with edges so sharp that it is almost impossible to walk upon them. In many places the rocks are honeycombed through the action of water, and subterranean passages connect inland waters with the sea. Caves, too, sometimes of considerable extent, are found at various places, especially

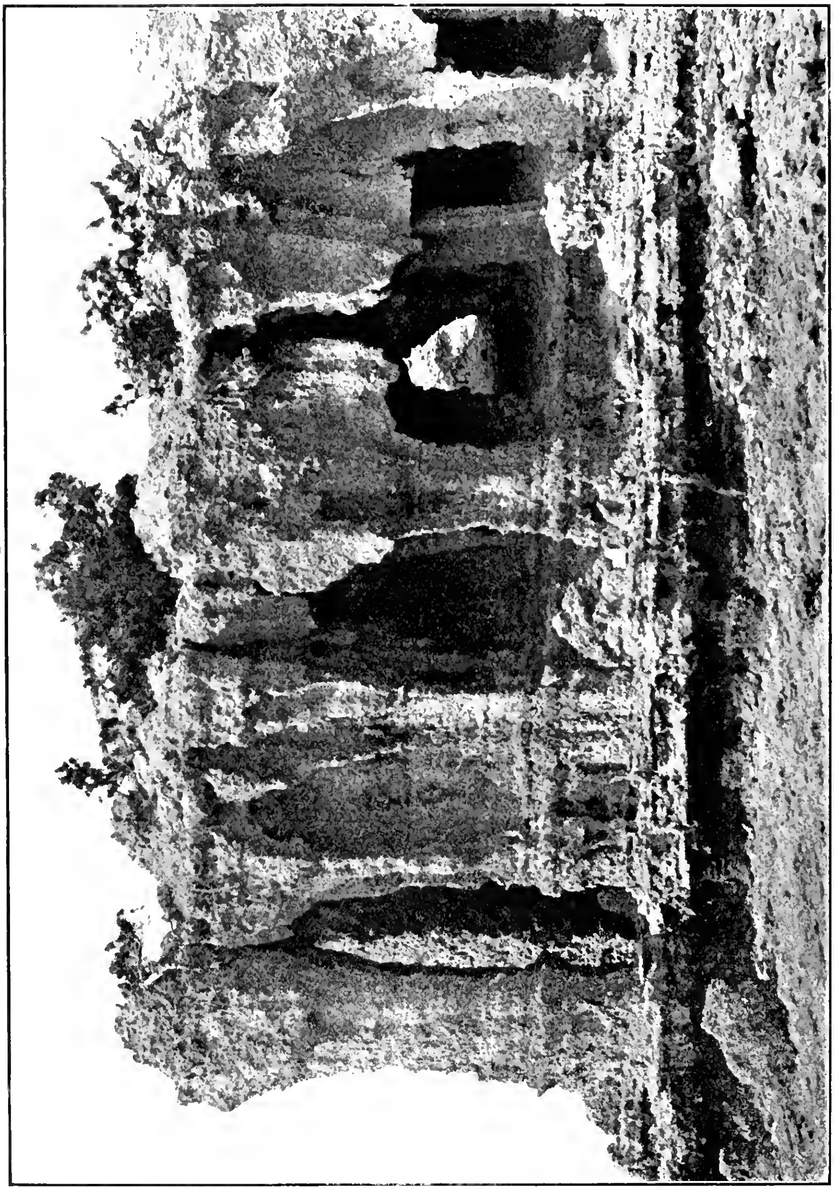


Fig. 9. Cathedral Rocks, looking North. Photograph by A. H. Verrill.

in the northern part of the islands, about Castle Harbor and Harrington Sound. The floors of these caves are in some places below sea level, and since there is a free communication with the sea, deep pools of sea water are not uncommon in them. The water is so clear and unruffled that the incautious visitor is liable to walk into the pools unawares, even after being especially cautioned against it. The stalactite and stalagmite formations point to the solvent action of water as the cause of the caves. It is highly probable that many of the depressed areas of the land known as 'sinks,' as well as the sounds and harbors, are the result of the falling in of the roofs of caves. The 'sinks' vary in area from a few square yards to many acres.

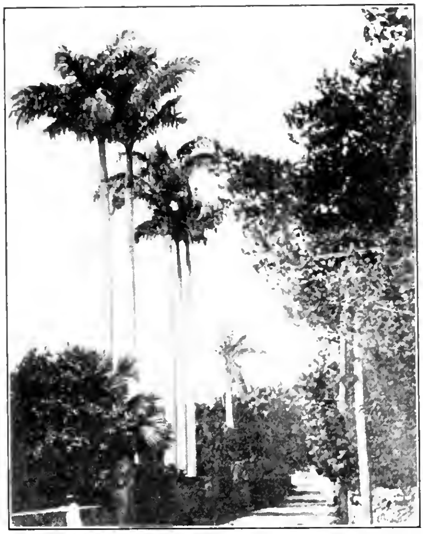


Fig. 10. Royal Palms at Pembroke Hall, near Hamilton.

These depressions contain the peculiar reddish brown earth that makes farming and gardening possible in the Bermudas. The richness of this soil and the favorable climate allow the farmer to keep the earth under constant cultivation and to procure several crops in the course of a year.

Although trees and shrubs in great variety are to be found in Bermuda, most of them are not peculiar to the islands, but probably owe their origin to introduction by natural agencies from the West Indies and the United States before historic times, while many are known to have been introduced by man, and not a few of these within comparatively recent times. The Bermuda cedar (*Juniperus bermudiana*) may be indigenous, though fifty years ago it was also found in the Blue Mountains of Jamaica. The palms—a dozen species of which are said to be growing in the islands—and the palmettos, are the most noticeable growths to attract the eye of the northener. The royal palm (Fig. 10) surpasses all others both in height and in beauty, but the cocoanut palm (Fig. 11) is a worthy second, and many specimens of it are striking features of the landscape. In Queen Street, Hamilton, one drives beneath the sprawling branches of what we call a 'rubber plant' when it grows in pots in our conservatories. Here its branches have a spread of a hundred feet or so. On entering the Public Garden at St. George's, where many interesting exotics are found, one is confronted by a stately screw pine of most symmetrical

form twenty or thirty feet high, and in the Agricultural Gardens near Hamilton, another *Pandanus* of less graceful form but greater breadth is seen. Our common deciduous trees, however,—the maples, beeches, birches and oaks—are entirely wanting. In a private garden that contained many interesting trees and shrubs from various parts of the world

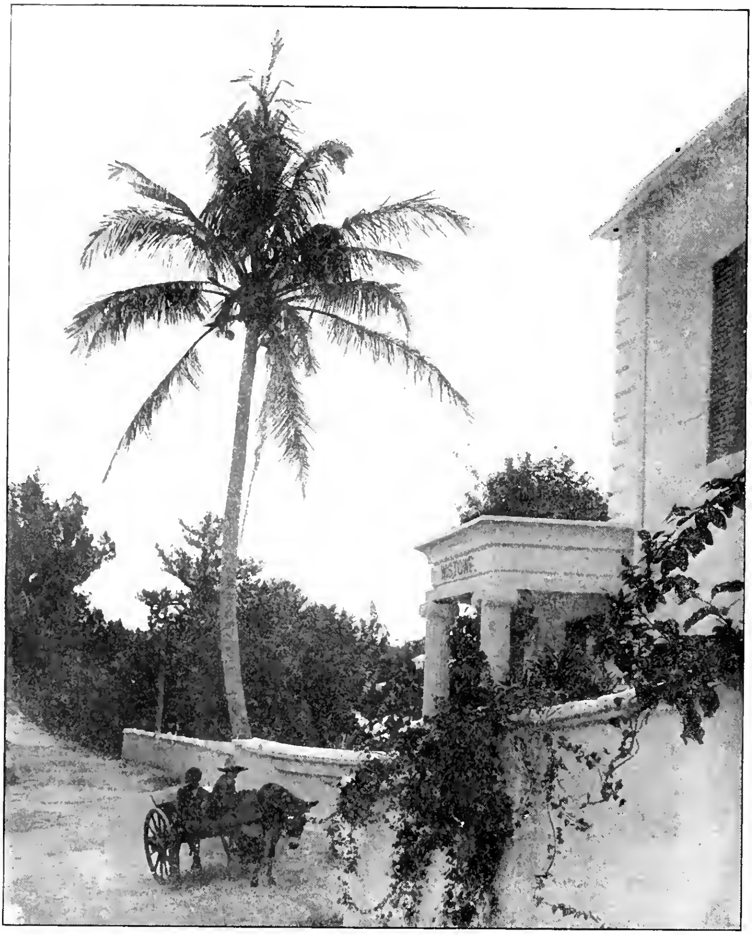


FIG. 11. 'WISTOWE,' RESIDENCE OF THE WIDOW OF THE LATE U. S. CONSUL, THE HON. C. H. ALLEN.

I was shown, as one of the greatest of curiosities, a sickly specimen of one of our oaks. Even with the utmost care and attention these trees can not be made to flourish in Bermuda; but oleanders have been introduced and flourish almost beyond belief. They are often used as hedgerows and grow to a height of twenty or twenty-five feet. A great variety of tints from deep scarlet—almost crimson—to pure white are to be seen. From May to September they enliven the face

of the land with their brilliant colors, which occur in such masses that they are the admiration of all who see them. On the bleak north shores, the tamarisk has been planted as a break against wind and salt-water. Though not an especially graceful shrub, the soft green of its fine-cut foliage makes a pleasant impression on the eye, and it enjoys the great practical advantage of being about the only kind of verdure that can really thrive in the presence of the abundant salt-spray which the prevailing winds drive in upon the land.

The fiddle-wood tree (*Citharexylum quadrangulare*) is to-day the commonest of the deciduous trees in Bermuda, but the first tree of this species on the islands—the one from which all the others are reported to have come—was imported as recently as 1830, and is still standing. The Pride of India (*Melia azedarach*) is a rather scraggy, forlorn looking tree in mid-summer, and one wonders why it is so much cultivated; but in early spring, before the leaves are out, it puts forth a profusion of pink flowers that makes it a great favorite with the Bermudians. It seems as though Bermuda must be the home of the genius *Hibiscus*, so many species are met with. In mid-summer their blossoms exhibit some remarkably gorgeous colors. Still, the most superb of all the ornamental trees and shrubs to be seen here is the *Poinciana regia*, a native of Madagascar, a tree with spreading branches clothed in the most pleasing green and decked with beautiful clusters of brilliant red blossoms.

The land animals, with the exception of insects and mollusks, are remarkably few, and of these most are probably not natives of the islands any more than are the majority of the phænogamic plants.

Except for domesticated animals, mammals are numerous neither in species nor in individuals. The most interesting one is doubtless the wood rat (*Mus tectorum*), which lives in trees and is now nearly extinct. This was at one time a dreaded scourge to the early settlers. Nearly 300 years ago (1619), Governor Butler, writing of the timely arrival of a so-called runaway frigate that brought food and thus averted impending famine, said:

> But howsoever this runne away frigate brought with her a timely and acceptable sacrifice of her meale; yet the companions of her meale, numbers of ratts (which wer the first that the ilands ever sawe), being received with-all and on a soudaine multiplyinge themselves by an infinite increase (for ther is noe place in the world so proper for them), within the space of one only yeare they became so terrible to the poore inhabitants, as that (like one of Pharaoths plagues) the whole plantation was almost utterly subverted therby; and so farr gone it was at last, that it proved Captaine Tucker's masterpiece all his time (which was not long after) to devise trapps and stratagems to conquer and destroye them, though indeed all of them proved to noe purpose (as you shall see hereafter) untill afterwards, one moneth of cold and wett weather did the deed.

It is by no means certain, however, that these rats had not long existed on the islands, even though an earlier writer—Silvanus Jourdan, says (1610):

> The countrey (foreasmuch as I could finde myself, or heare by others) affords no venimous creature or so much as a Rat or a mouse, or any other thing unwholesome.

Whales, which were once of some commercial importance to the islands, are so rare that they are no longer hunted, and the 'whale houses,' of which there were recently half a dozen in existence, are but relics of an industry that has practically ceased.

The greater part of the 150 or more birds mentioned by Major Wedderburn (Jones: 'The Naturalist in Bermuda') as found in the Bermudas, are migrants. The most conspicuous and interesting

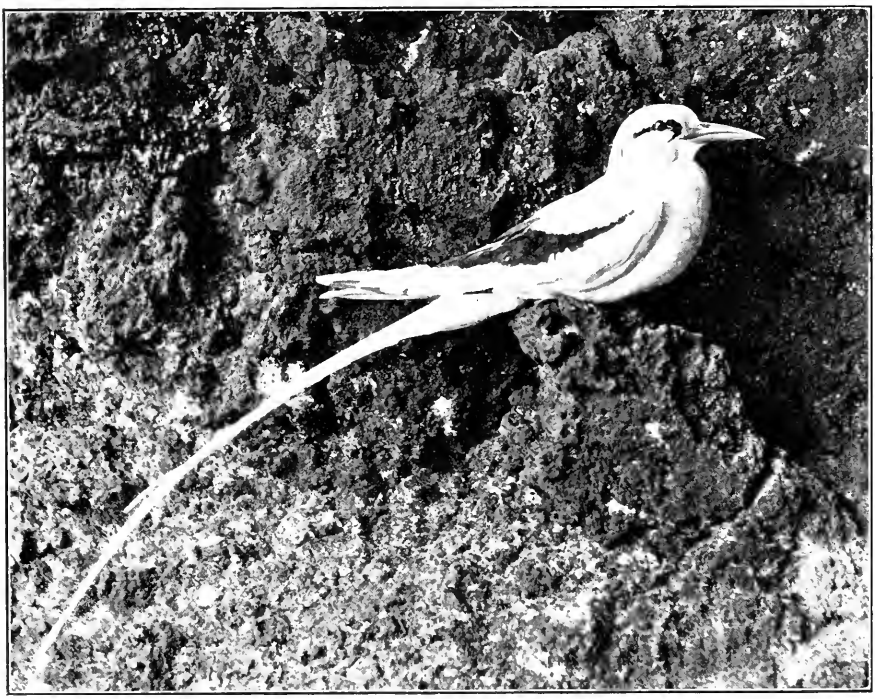


FIG. 12. TROPIC BIRDS. Photograph by A. H. Verrill.

of them is the tropic or boatswain bird (Fig. 12), which still continues to nest here, usually on the more remote and inaccessible islands.

The only representative of the Amphibia is the great Surinam toad (*Bufo agua*), which was introduced into Bermuda some twenty-five or thirty years ago by Captain Nathaniel Vesey to combat insect pests. I was fortunate enough during my first visit to the islands to find several of these toads spawning on the morning of April 22. There

had been a heavy shower during the preceding night, which had resulted in temporary pools of fresh water in a few places, and it was in one of these pools near Spittal Pond that a half dozen or more pairs were found. A quantity of the spawn was secured and a series of eggs preserved.

Reptiles have at present very few representatives. There are no snakes, and the possible importation of them is carefully guarded against. The only land reptile is the Bermuda lizard (*Eumices longirostris*), which is not found elsewhere and is probably indigenous. Of turtles, four species, none of which is peculiar to Bermuda, are known to frequent the islands:—the green turtle (*Chelonia mydas*), the hawk bill (*Eretmochelys imbricata*), the logger-head (*Thalassochelys caouana*) and the trunk or leather turtle (*Sphargis coriacea*). The green turtle is still caught in nets in small numbers, but the others are found only occasionally. From the accounts of several of the early writers on Bermuda it is evident that some of the turtles (perhaps the green turtle) were once very abundant. Sylvanus Jourdan, writing of the shipwreck of Sir George Somers in 1609, says:

> There are also great store of Tortoises (which some call turtles), and those so great, that I have seene a bushell of egges in one of their bellies, which are sweeter than any Henne egge: and the Tortoise itselfe is all very goode meate, and yieldeth great store of oyle, which is as sweete as any butter: and one of them will suffice fifty men a meale at least: and of these hath beene taken great store, with two boates at the least forty in one day . . . We carried with vs also a good portion of Tortoise oyle, which either for frying or baking did vs very great pleasure, it being very sweete nourishing and wholesome.

An early account of their egg-laying, by Peter Martyr, is given in these words:

> At such time as the heate of Nature moueth them to generation, they come forthe of the Sea, and making a deepe pit in the sand, they lay three or foure hundred Egges therein: when they haue thus emptied their bag of Conception, they put as much of the same againe into the Pit as may satisfie to couer their Egges, and so resorte againe vnto the Sea, nothing carefull of their succession. At the day appointed of Nature to the procreation of these creatures there creepeth out a multitude of Tortoyses, as it were Pismyers out of an anthill, and this only by the heate of the Sunne, without any helpe of their Parents: their Egges are as big as Geese Egges, and themselues growne to perfection, bigger than great round Targets.

It is, however, the richness of the life in the sea—in marked contrast to the paucity of that on land—which is the chief source of attraction to the zoologist. If the gardens on the land require much attention and are the reflection of man's assiduity in transplanting the products of one country to the soil of another, the gardens of the sea demand no such care, and man has had little or nothing to do with shaping the wonderful display of marine life that carpets the floors of the broad lagoons and the reefs of the Bermuda plateau.

(To be concluded.)

A STUDY OF THE DEVELOPMENT OF GEOMETRIC METHODS.*

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TO appreciate the progress geometry has made during the century just ended, it is of advantage to cast a rapid glance over the state of mathematical science at the beginning of the nineteenth century.

We know that, in the last period of his life, Lagrange, fatigued by the researches in analysis and mechanics, which assured him, however, an immortal glory, neglected mathematics for chemistry, which, according to him, was easy as algebra, for physics, for philosophic speculations.

This mood of Lagrange we almost always find at certain moments of the life of the greatest savants. The new ideas which came to them in the fecund period of youth and which they introduced into the common domain have given them all they could have expected; they have fulfilled their task and feel the need of turning their mental activity towards wholly new subjects. This need, as we recognize, manifested itself with particular force at the epoch of Lagrange. At this moment, in fact, the program of researches opened to geometers by the discovery of the infinitesimal calculus appeared very nearly finished up. Some differential equations more or less complicated to integrate, some chapters to add to the integral calculus, and one seemed about to touch the very outmost bounds of science.

Laplace had achieved the explanation of the system of the world and laid the foundations of molecular physics. New ways opened before the experimental sciences and prepared the astonishing development they received in the course of the century just ended. Ampère, Poisson, Fourier and Cauchy himself, the creator of the theory of imaginaries, were occupied above all in studying the application of the analytic methods to mechanics, and seemed to believe that outside this new domain, which they hastened to cover, the outlines of theory and science were finally fixed.

Modern geometry, a glory we must claim for it, came, after the end of the eighteenth century, to contribute in large measure to the renewing of all mathematical science, by offering to research a way

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new and fertile, and above all in showing us, by brilliant successes, that general methods are not everything in science, and that even in the simplest subject there is much for an ingenious and inventive mind to do.

The beautiful geometric demonstrations of Huygens, of Newton and of Clairaut were forgotten or neglected. The fine ideas introduced by Desargues and Pascal had remained without development and appeared to have fallen on sterile ground.

Carnot, by his 'Essai sur les transversales' and his 'Géométrie de position,' above all Monge, by the creation of descriptive geometry and by his beautiful theories on the generation of surfaces, came to renew a chain which seemed broken. Thanks to them, the conceptions of the inventors of analytic geometry, Descartes and Fermat, retook alongside the infinitesimal calculus of Leibnitz and Newton the place they had lost, yet should never have ceased to occupy. With his geometry, said Lagrange, speaking of Monge, this demon of a man will make himself immortal.

And, in fact, not only has descriptive geometry made it possible to coordinate and perfect the procedures employed in all the arts where precision of form is a condition of success and of excellence for the work and its products; but it appeared as the graphic translation of a geometry, general and purely rational, of which numerous and important researches have demonstrated the happy fertility.

Moreover, beside the 'Géométrie descriptive' we must not forget to place that other master-piece, the 'Application de l'analyse à la géométrie'; nor should we forget that to Monge are due the notion of lines of curvature and the elegant integration of the differential equation of these lines for the case of the ellipsoid, which, it is said, Lagrange envied him. To be stressed is this character of unity of the work of Monge.

The renewer of modern geometry has shown us from the beginning, what his successors have perhaps forgotten, that the alliance of geometry and analysis is useful and fruitful, that this alliance is perhaps for each a condition of success.

II.

In the school of Monge were formed many geometers: Hachette, Brianchon, Chappuis, Binet, Lancret, Dupin, Malus, Gaultier de Tours, Poncelet, Chasles, etc. Among these Poncelet takes first rank. Neglecting, in the works of Monge, everything pertaining to the analysis of Descartes or concerning infinitesimal geometry, he devoted himself exclusively to developing the germs contained in the purely geometric researches of his illustrious predecessor.

Made prisoner by the Russians in 1813 at the passage of the

Dnieper and incarcerated at Saratoff, Poncelet employed the leisure captivity left him in the demonstration of the principles which he has developed in the 'Traité des propriétés projectives des figures,' issued in 1822, and in the great memoirs on reciprocal polars and on harmonic means, which go back nearly to the same epoch. So we may say the modern geometry was born at Saratoff.

Renewing the chain broken since Pascal and Desargues, Poncelet introduced at the same time homology and reciprocal polars, putting thus in evidence, from the beginning, the fruitful ideas on which the science has evolved during fifty years.

Presented in opposition to analytic geometry, the methods of Poncelet were not favorably received by the French analysts. But such were their importance and their novelty, that without delay they aroused, from divers sides, the most profound researches.

Poncelet had been alone in discovering the principles; on the contrary, many geometers appeared almost simultaneously to study them on all sides and to deduce from them the essential results which they implicitly contained.

At this epoch, Gergonne was brilliantly editing a periodical which has to-day for the history of geometry an inestimable value. The *Annales de Mathématiques,* published at Nîmes from 1810 to 1831. was during more than fifteen years the only journal in the entire world devoted exclusively to mathematical researches.

Gergonne, who, in many regards, was a model editor for a scientific journal, had the defects of his qualities; he collaborated, often against their will, with the authors of the memoirs sent him, rewrote them, and sometimes made them say more or less than they would have wished. Be that as it may, he was greatly struck by the originality and range of Poncelet's discoveries.

In geometry some simple methods of transformation of figures were already known; homology even had been employed in the plane, but without extending it to space, as did Poncelet, and especially without recognizing its power and fruitfulness. Moreover all these transformations were *punctual,* that is to say they made correspond a point to a point.

In introducing polar reciprocals, Poncelet was in the highest degree creative, because he gave the first example of a transformation in which to a point corresponded something other than a point.

Every method of transformation enables us to multiply the number of theorems, but that of polar reciprocals had the advantage of making correspond to a proposition another proposition of wholly different aspect. This was a fact essentially new. To put it in evidence, Gergonne invented the system, which since has had so much success, of memoirs printed in double columns with correlative

propositions in juxtaposition; and he had the idea of substituting for Poncelet's demonstrations, which required an intermediary curve or surface of the second degree, the famous 'principle of duality,' of which the signification, a little vague at first, was sufficiently cleared up by the discussions which took place on this subject between Gergonne, Poncelet and Pluecker.

Bobillier, Chasles, Steiner, Lamé, Sturm, and many others whose names escape me, were, at the same time as Pluecker and Poncelet, assiduous collaborators of the *Annales de Mathématiques*. Gergonne having become rector of the Acadamy of Montpellier, was forced to suspend in 1831 the publication of his journal. But the success it had obtained, the taste for research it had contributed to develop, had commenced to bear their fruit. Quetelet had established in Belgium the *Correspondance mathématique et physique*. Crelle, from 1826, brought out at Berlin the first sheets of his celebrated journal, where he published the memoirs of Abel, of Jacobi, of Steiner.

A great number of separate works began also to appear, wherein the principles of modern geometry were powerfully expounded and developed.

First came in 1827 the 'barycentrische Calcul' of Moebius, a work truly original, remarkable for the profundity of its conceptions, the elegance and the rigor of its exposition; then in 1828 the 'Analytisch-geometrische Entwickelungen' of Pluecker, of which the second part appeared in 1831 and which was soon followed by the 'System der analytischen Geometrie' of the same author published at Berlin in 1835.

In 1832 Steiner brought out at Berlin his great work: 'Systematische Entwickelung der Abhaengigkeit der geometrischen Gestalten von einander,' and, the following year, 'Die geometrischen Konstruktionen ausgefuehrt mittels der geraden Linie und eines festen Kreises,' where was confirmed by the most elegant examples a proposition of Poncelet's relative to the employment of a single circle for the geometric constructions.

Finally, in 1830, Chasles sent to the Academy of Brussels, which happily inspired had offered a prize for a study of the principles of modern geometry, his celebrated 'Aperçu historique sur l'origine et le développement des méthodes en géométrie,' followed by 'Mémoire sur deux principes généraux de la science: la dualité et l'homographie,' which was published only in 1837.

Time would fail us to give a worthy appreciation of these beautiful works and to apportion the share of each. Moreover, to what would such a study conduct us, but to a new verification of the general laws of the development of science. When the times are ripe, when the fundamental principles have been recognized and enunciated, nothing

stops the march of ideas; the same discoveries, or discoveries almost equivalent, appear at nearly the same instant, and in places the most diverse. Without undertaking a discussion of this sort, which, besides, might appear useless or become irritating, it is, however, of importance to bring out a fundamental difference between the tendencies of the great geometers who, about 1830, gave to geometry a scope before unknown.

III.

Some, like Chasles and Steiner, who consecrated their entire life to research in pure geometry, opposed what they called *synthesis* to *analysis* and, adopting in the ensemble if not in detail the tendencies of Poncelet, proposed to constitute an independent doctrine, rival of Descartes' analysis.

Poncelet could not content himself with the insufficient resources furnished by the method of projections; to attain imaginaries he created that famous *principle of continuity* which gave birth to such long discussions between him and Cauchy.

Suitably enunciated, this principle is excellent and can render great service. Poncelet was wrong in refusing to present it as a simple consequence of analysis; and Cauchy, on the other hand, was not willing to recognize that his own objections, applicable without doubt to certain transcendent figures, were without force in the applications made by the author of the 'Traité des propriétés projectives.'

Whatever be the opinion of such a discussion, it showed at least in the clearest manner that the geometric system of Poncelet rested on an analytic foundation, and besides we know, by the untoward publication of the manuscripts of Saratoff, that by the aid of Descartes' analysis were established the principles which serve as foundation for the 'Traité des propriétés projectives.'

Younger than Poncelet, who besides abandoned geometry for mechanics where his works had a preponderant influence, Chasles, for whom was created in 1847 a chair of *Géométrie supérieure* in the Faculty of Science of Paris, endeavored to constitute a geometric doctrine entirely independent and autonomous. He has expounded it in two works of high importance, the 'Traité de géométrie supérieure,' which dates from 1852, and the 'Traité des sections coniques,' unhappily unfinished and of which the first part alone appeared in 1865.

In the preface of the first of these works he indicates very clearly the three fundamental points which permit the new doctrine to share the advantages of analysis and which to him appear to mark an advance in the cultivation of the science. These are: (1) The introduction of the principle of signs, which simplifies at once the enunciations and the demonstrations, and gives to Carnot's analysis of transversals all the scope of which it is susceptible; (2) the introduction of

imaginaries, which supplies the place of the principle of continuity and furnishes demonstrations as general as those of analytic geometry; (3) the simultaneous demonstration of propositions which are correlative, that is to say, which correspond in virtue of the principle of duality.

Chasles studies indeed in his work homography and correlation; but he avoids systematically in his exposition the employment of transformations of figures, which, he thinks, can not take the place of direct demonstrations since they mask the origin and the true nature of the properties obtained by their means.

There is truth in this judgment, but the advance itself of the science permits us to declare it too severe. If it happens often that, employed without discernment, transformations multiply uselessly the number of theorems, it must be recognized that they often aid us to better understand the nature of the propositions even to which they have been applied. Is it not the employment of Poncelet's projection which has led to the so fruitful distinction between projective properties and metric properties, which has taught us also the high importance of that cross ratio whose essential property is found already in Pappus, and of which the fundamental rôle has begun to appear after fifteen centuries only in the researches of modern geometry?

The introduction of the principle of signs was not as new as Chasles supposed at the time he wrote his 'Traité de Géométrie supérieure.'

Moebius, in his *barycentrische Calcul*, had already given issue to a *desideratum* of Carnot, and employed the signs in a way the largest and most precise, defining for the first time the sign of a segment and even that of an area.

Later he succeeded in extending the use of signs to lengths not laid off on the same straight and to angles not formed about the same point.

Besides Grassmann, whose mind has so much analogy to that of Moebius, had necessarily employed the principle of signs in the definitions which serve as basis for his methods, so original, of studying the properties of space.

The second characteristic which Chasles assigns to his system of geometry is the employment of imaginaries. Here, his method was really new and he illustrates it by examples of high interest. One will always admire the beautiful theories he has left us on homofocal surfaces of the second degree, where all the known properties and others new, as varied as elegant, flow from the general principle that they are inscribed in the same developable circumscribed to the circle at infinity.

But Chasles introduced imaginaries only by their symmetric func-

tions, and consequently would not have been able to define the cross ratio of four elements when these ceased to be real in whole or in part. If Chasles had been able to establish the notion of the cross ratio of imaginary elements, a formula he gives in the 'Géométrie supérieure' (p. 118 of the new edition) would have immediately furnished him that beautiful definition of angle as logarithm of a cross ratio which enabled Laguerre, our regretted confrère, to give the complete solution, sought so long, of the problem of the transformation of relations which contain at the same time angles and segments in homography and correlation.

Like Chasles, Steiner, the great and profound geometer, followed the way of pure geometry; but he has neglected to give us a complete exposition of the methods upon which he depended. However, they may be characterized by saying that they rest upon the introduction of those elementary geometric forms which Desargues had already considered, on the development he was able to give to Bobillier's theory of polars, and finally on the construction of curves and surfaces of higher degrees by the aid of sheaves or nets of curves of lower orders. In default of recent researches, analysis would suffice to show that the field thus embraced has just the extent of that into which the analysis of Descartes introduces us without effort.

IV.

While Chasles, Steiner, and, later, as we shall see, von Staudt, were intent on constituting a rival doctrine to analysis and set in some sort altar against altar, Gergonne, Bobillier, Sturm, above all Pluecker, perfected the geometry of Descartes and constituted an analytic system in a manner adequate to the discoveries of the geometers.

It is to Bobillier and to Pluecker that we owe the method called *abridged notation.* Bobillier consecrated to it some pages truly new in the last volumes of the *Annales* of Gergonne.

Pluecker commenced to develop it in his first work, soon followed by a series of works where are established in a fully conscious manner the foundations of the modern analytic geometry. It is to him that we owe tangential coordinates, trilinear coordinates, employed with homogeneous equations, and finally the employment of canonical forms whose validity was recognized by the method, so deceptive sometimes, but so fruitful, called the *enumeration of constants.*

All these happy acquisitions infused new blood into Descartes' analysis and put it in condition to give their full signification to the conceptions of which the geometry called *synthetic* had been unable to make itself completely mistress.

Pluecker, to whom it is without doubt just to adjoin Bobillier, carried off by a premature death, should be regarded as the veritable

initiator of those methods of modern analysis where the employment of homogeneous coordinates permits treating simultaneously and, so to say, without the reader perceiving it, together with one figure all those deducible from it by homography and correlation.

V.

Parting from this moment, a period opens brilliant for geometric researches of every nature.

The analysts interpret all their results and are occupied in translating them by constructions.

The geometers are intent on discovering in every question some general principle, usually undemonstrable without the aid of analysis, in order to make flow from it without effort a crowd of particular consequences, solidly bound to one another and to the principle whence they are derived. Otto Hesse, brilliant disciple of Jacobi, develops in an admirable manner that method of homogeneous coordinates to which Pluecker perhaps had not attached its full value. Boole discovers in the polars of Bobillier the first notion of a covariant; the theory of forms is created by the labors of Cayley, Sylvester, Hermite, Brioschi. Later Aronhold, Clebsch and Gordan and other geometers still living gave to it its final notation, established the fundamental theorem relative to the limitation of the number of covariant forms and so gave it all its amplitude.

The theory of surfaces of the second order, built up principally by the school of Monge, was enriched by a multitude of elegant properties, established principally by O. Hesse, who found later in Paul Serret a worthy emulator and continuer.

The properties of the polars of algebraic curves are developed by Pluecker and above all by Steiner. The study, already old, of curves of the third order is rejuvenated and enriched by a crowd of new elements. Steiner, the first, studies by pure geometry the double tangents of curves of the fourth order, and Hesse, after him, applies the methods of algebra to this beautiful question, as well as to that of points of inflection of curves of the third order.

The notion of *class* introduced by Gergonne, the study of a paradox in part elucidated by Poncelet and relative to the respective degrees of two curves reciprocal polars one of the other, give birth to the researches of Pluecker relative to the singularities called *ordinary* of algebraic plane curves. The celebrated formulas to which Pluecker is thus conducted are later extended by Cayley and by other geometers to algebraic skew curves, by Cayley again and by Salmon to algebraic surfaces.

The singularities of higher order are in their turn taken up by the geometers; contrary to an opinion then very widespread, Halphen

demonstrates that each of these singularities can not be considered as equivalent to a certain group of ordinary singularities and his researches close for a time this difficult and important question.

Analysis and geometry, Steiner, Cayley, Salmon, Cremona, meet in the study of surfaces of the third order, and, in conformity with the anticipations of Steiner, this theory becomes as simple and as easy as that of surfaces of the second order.

The algebraic ruled surfaces, so important for applications, are studied by Chasles, by Cayley, of whom we find the influence and the mark in all mathematical researches, by Cremona, Salmon, La Gournerie; so they will be later by Pluecker in a work to which we must return.

The study of the general surface of the fourth order would seem to be still too difficult; but that of the particular surfaces of this order with multiple points or multiple lines is commenced, by Pluecker for the surface of waves, by Steiner, Kummer, Cayley, Moutard, Laguerre, Cremona and many other investigators.

As for the theory of algebraic skew curves, grown rich in its elementary parts, it receives finally, by the labors of Halphen and of Noether, whom it is impossible for us here to separate, the most notable extensions.

A new theory with a great future is born by the labors of Chasles, of Clebsch and of Cremona; it concerns the study of all the algebraic curves which can be traced on a determined surface.

Homography and correlation, those two methods of transformation which have been the distant origin of all the preceding researches, receive from them in their turn an unexpected extension; they are not the only methods which make a single element correspond to a single element, as might have shown a particular transformation briefly indicated by Poncelet in the 'Traité des propriétés projectives.'

Pluecker defines the *transformation by reciprocal radii vectores* or *inversion,* of which Sir W. Thomson and Liouville hasten to show all the importance, as well for mathematical physics as for geometry.

A contemporary of Moebius and Pluecker, Magnus believed he had found the most general transformation which makes a point correspond to a point, but the researches of Cremona teach us that the transformation of Magnus is only the first term of a series of birational transformations which the great Italian geometer teaches us to determine methodically, at least for the figures of plane geometry.

The Cremona transformations long retained a great interest, though later researches have shown us that they reduce always to a series of successive applications of the transformation of Magnus.

VI.

All the works we have enumerated, others to which we shall return later, find their origin and, in some sort, their first motive in the conceptions of modern geometry; but the moment has come to indicate rapidly another source of great advances for geometric studies. Legendre's theory of elliptic functions, too much neglected by the French geometers, is developed and extended by Abel and Jacobi. With these great geometers, soon followed by Riemann and Weierstrass, the theory of Abelian functions which, later, algebra would try to follow solely with its own resources, brought to the geometry of curves and surfaces a contribution whose importance will continue to grow.

Already, Jacobi had employed the analysis of elliptic functions in the demonstration of Poncelet's celebrated theorems on inscribed and circumscribed polygons, inaugurating thus a chapter since enriched by a multitude of elegant results; he had obtained also, by methods pertaining to geometry, the integration of Abelian equations.

But it was Clebsch who first showed in a long series of works all the importance of the notion of *deficiency* (Geschlecht, genre) of a curve, due to Abel and Riemann, in developing a crowd of results and elegant solutions that the employment of Abelian integrals would seem, so simple was it, to connect with their veritable point of departure.

The study of points of inflection of curves of the third order, that of double tangents of curves of the fourth order and, in general, the theory of osculation on which the ancients and the moderns had so often practised, were connected with the beautiful problem of the division of elliptic functions and Abelian functions.

In one of his memoirs, Clebsch had studied the curves which are *rational* or of deficiency zero; this led him, toward the end of his too short life, to envisage what may be called also *rational* surfaces, those which can be simply represented by a plane. This was a vast field for research, opened already for the elementary cases by Chasles, and in which Clebsch was followed by Cremona and many other savants. It was on this occasion that Cremona, generalizing his researches on plane geometry, made known not indeed the totality of birational transformations of space, but certain of the most interesting among these transformations.

The extension of the notion of deficiency to algebraic surfaces is already commenced; already also works of high value have shown that the theory of integrals, simple or mutiple, of algebraic differentials will find, in the study of surfaces as in that of curves, an ample field of important applications; but it is not proper for the reporter on geometry to dilate on this subject.

VII.

While thus were constituted the mixed methods whose principal applications we have just indicated, the pure geometers were not inactive. Poinsot, the creator of the theory of couples, developed, by a method purely geometric, 'that, said he, where one never for a moment loses from view the object of the research,' the theory of the rotation of a solid body that the researches of d'Alembert, Euler and Lagrange seemed to have exhausted: Chasles made a precious contribution to kinematic by his beautiful theorems on the displacement of a solid body, which have since been extended by other elegant methods to the case where the motion has divers degrees of freedom. He made known those beautiful propositions on attraction in general, which figure without disadvantage beside those of Green and Gauss.

Chasles and Steiner met in the study of the attraction of ellipsoids and showed thus once more that geometry has its designated place in the highest questions of the integral calculus.

Steiner did not disdain at the same time to occupy himself with the elementary parts of geometry. His researches on the contacts of circles and conics, on isoperimetric problems, on parallel surfaces, on the center of gravity of curvature, excited the admiration of all by their simplicity and their depth.

Chasles introduced his principle of correspondence between two variable objects which has given birth to so many applications; but here analysis re-took its place to study the principle in its essence, make it precise and generalize it.

It was the same concerning the famous theory of *characteristics* and the numerous researches of de Jonquières, Chasles, Cremona and still others, which gave the foundations of a new branch of the science, *Enumerative Geometry*.

During many years, the celebrated postulate of Chasles was admitted without any objection: a crowd of geometers believed they had established it in a manner irrefutable.

But, as Zeuthen then said, it is very difficult to recognize whether, in demonstrations of this sort, there does not exist always some weak point that their author has not perceived; and, in fact, Halphen, after fruitless efforts, crowned finally all these researches by clearly indicating in what cases the postulate of Chasles may be admitted and in what cases it must be rejected.

VIII.

Such are the principal works which restored geometric synthesis to honor and assured to it, in the course of the last century, the place belonging to it in mathematical research.

Numerous and illustrious workers took part in this great geometric movement, but we must recognize that its chiefs and leaders were Chasles and Steiner. So brilliant were their marvelous discoveries that they threw into the shade, at least momentarily, the publications of other modest geometers, less preoccupied perhaps in finding brilliant applications, fitted to evoke love for geometry, than to establish this science itself on an absolutely solid foundation.

Their works have received perhaps a recompense more tardy, but their influence grows each day; it will without doubt increase still more. To pass them over in silence would be without doubt to neglect one of the principal factors which will enter into future researches.

We allude at this moment above all to von Staudt. His geometric works were published in two books of grand interest: the 'Geometrie der Lage,' issued in 1847, and the 'Beiträge zur Geometrie der Lage,' published in 1856, that is to say, four years after the 'Géométrie supérieure.'

Chasles, as we have seen, had devoted himself to constituting a body of doctrine independent of Descartes' analysis and had not completely succeeded. We have already indicated one of the criticisms that can be made upon this system: the imaginary elements are there defined only by their symmetric functions, which necessarily excludes them from a multitude of researches. On the other hand, the constant employment of cross ratio, of transversals and of involution, which requires frequent analytic transformations, gives to the 'Géométrie supérieure' a character almost exclusively metric which removes it notably from the methods of Poncelet. Returning to these methods, von Staudt devoted himself to constituting a geometry freed from all metric relation and resting exclusively on relations of situation.

This is the spirit in which was conceived his first work, the 'Geometrie der Lage' of 1847. The author there takes as point of departure the harmonic properties of the complete quadrilateral and those of homologic triangles, demonstrated uniquely by considerations of geometry of three dimensions, analogous to those of which the School of Monge made such frequent use.

In this first part of his work, von Staudt neglected entirely imaginary elements. It is only in the *Beiträge*, his second work, that he succeeds, by a very original extension of the method of Chasles, in defining geometrically an isolated imaginary element and distinguishing it from its conjugate.

This extension, although rigorous, is difficult and very abstract. It may be defined in substance as follows: Two conjugate imaginary points may always be considered as the double points of an involution on a real straight; and just as one passes from an imaginary to its conjugate by changing i into $-i$, so one may distinguish the two

imaginary points by making correspond to each of them one of the two different senses which may be attributed to the straight. In this there is something a little artificial; the development of the theory erected on such foundations is necessarily complicated. By methods purely projective, von Staudt establishes a calculus of cross ratios of the most general imaginary elements. Like all geometry, the projective geometry employs the notion of order and order engenders number; we are not astonished therefore that von Staudt has been able to constitute his calculus; but we must admire the ingenuity displayed in attaining it. In spite of the efforts of distinguished geometers who have essayed to simplify its exposition, we fear that this part of the geometry of von Staudt, like the geometry otherwise so interesting of the profound thinker Grassmann, can not prevail against the analytic methods which have won to-day favor almost universal.

Life is short; geometers know and also practise the principle of least action. Despite these fears, which should discourage no one, it seems to us that under the first form given it by von Staudt, projective geometry must become the necessary companion of descriptive geometry, that it is called to renovate this geometry in its spirit, its procedures and its applications.

This has already been comprehended in many countries, and notably in Italy where the great geometer Cremona did not disdain to write, for the schools, an elementary treatise on projective geometry.

IX.

In the preceding articles, we have essayed to follow and bring out clearly the most remote consequences of the methods of Monge and Poncelet. In creating tangential coordinates and homogeneous coordinates, Pluecker seemed to have exhausted all that the method of projections and that of reciprocal polars could give to analysis.

It remained for him, toward the end of his life, to return to his first researches to give them an extension enlarging to an unexpected degree the domain of geometry.

Preceded by innumerable researches on systems of straight lines, due to Poinsot, Moebius, Chasles, Dupin, Malus, Hamilton, Kummer, Transon, above all to Cayley, who first introduced the notion of the coordinates of the straight, researches originating perhaps in statics and kinematics, perhaps in geometrical optics, Pluecker's geometry of the straight line will always be regarded as the part of his work where are met the newest and most interesting ideas.

That Pluecker first set up a methodic study of the straight line, that already is important, but that is nothing beside what he discovered. It is sometimes said that the principle of duality shows that

the plane as well as the point may be considered as a space element. That is true; but in adding the straight line to the plane and point as possible space element, Pluecker was led to recognize that any curve, any surface, may also be considered as space element, and so was born a new geometry which already has inspired a great number of works, which will raise up still more in the future.

A beautiful discovery, of which we shall speak further on, has already connected the geometry of spheres with that of straight lines and permits the introduction of the notion of coordinates of a sphere.

The theory of systems of circles is already commenced; it will be developed without doubt when one wishes to study the representation, which we owe to Laguerre, of an imaginary point in space by an oriented circle.

But before expounding the development of these new ideas which have vivified the infinitesimal methods of Monge, it is necessary to go back to take up the history of branches of geometry that we have neglected until now.

X.

Among the works of the school of Monge, we have hitherto confined ourselves to the consideration of those connected with *finite* geometry; but certain of the disciples of Monge devoted themselves above all to developing the new notions of infinitesimal geometry applied by their master to curves of double curvature, to lines of curvature, to the generation of surfaces, notions expounded at least in part in the 'Application de l'Analyse à la Géométrie.' Among these we must cite Lancret, author of beautiful works on skew curves, and above all Charles Dupin, the only one perhaps who followed all the paths opened by Monge

Among other works, we owe to Dupin two volumes Monge would not have hesitated to sign: the 'Développements de Géométrie pure,' issued in 1813 and the 'Applications de Géométrie et de Méchanique,' dating from 1822.

There we find the notion of *indicatrix,* which was to renovate, after Euler and Meunier, all the theory of curvature, that of conjugate tangents, of asymptotic lines which have taken so important a place in recent researches. Nor should we forget the determination of the surface of which all the lines of curvature are circles, nor above all the memoir on triple systems of orthogonal surfaces where is found, together with the discovery of the triple system formed by surfaces of the second degree, the celebrated theorem to which the name of Dupin will remain attached.

Under the influence of these works and of the renaissance of synthetic methods, the geometry of infinitesimals re-took in all researches the place Lagrange had wished to take away from it forever.

Singular thing, the geometric methods thus restored were to receive the most vivid impulse in consequence of the publication of a memoir which, at least at first blush, would appear connected with the purest analysis; we mean the celebrated paper of Gauss: 'Disquisitiones generales circa superficies curvas' which was presented in 1827 to the Göttingen Society, and whose appearance marked, one may say, a decisive date in the history of infinitesimal geometry.

From this moment, the infinitesimal method took in France a free scope before unknown.

Frenet, Bertrand, Molins, J. A. Serret, Bouquet, Puiseux, Ossian Bonnet, Paul Serret, develop the theory of skew curves. Liouville, Chasles, Minding, join them to pursue the methodic study of the memoir of Gauss.

The integration made by Jacobi of the differential equation of the geodesic lines of the ellipsoid started a great number of researches. At the same time the problems studied in the 'Application de l'Analyse' of Monge were greatly developed.

The determination of all the surfaces having their lines of curvature plane or spheric completed in the happiest manner certain partial results already obtained by Monge.

At this moment, one of the most penetrating of geometers, according to the judgment of Jacobi, Gabriel Lamé, who, like Charles Sturm, had commenced with pure geometry and had already made to this science contributions the most interesting by a little book published in 1817 and by memoirs inserted in the *Annales* of Gergonne, utilized the results obtained by Dupin and Binet on the system of confocal surfaces of the second degree and, rising to the idea of curvilinear coordinates in space, became the creator of a wholly new theory destined to receive in mathematical physics the most varied applications.

XI.

Here again, in this infinitesimal branch of geometry are found the two tendencies we have pointed out *à propos* of the geometry of finite quantities.

Some, among whom must be placed J. Bertrand and O. Bonnet, wish to constitute an independent method resting directly on the employment of infinitesimals. The grand 'Traité de Calcul différentiel,' of Bertrand, contains many chapters on the theory of curves and of surfaces, which are, in some sort, the illustration of this conception.

Others follow the usual analytic ways, being only intent to clearly recognize and put in evidence the elements which figure in the first plan. Thus did Lamé in introducing his theory of *differential parameters*. Thus did Beltrami in extending with great ingenuity the employment of these differential invariants to the case of two independent variables, that is to say, to the study of surfaces.

It seems that to-day is accepted a mixed method whose origin is found in the works of Ribaucour, under the name *périmorphie.* The rectangular axes of analytic geometry are retained, but made mobile and attached as seems best to the system to be studied. Thus disappear most of the objections which have been made to the method of coordinates. The advantages of what is sometimes called *intrinsic* geometry are united to those resulting from the use of the regular analysis. Besides, this analysis is by no means abandoned; the complications of calculation which it almost always carries with it, in its applications to the study of surfaces and rectilinear coordinates, usually disappear if one employs the notion on the invariants and the covariants of quadratic powers of differentials which we owe to the researches of Lipschitz and Christoffel, inspired by Riemann's studies on the non-Euclidean geometry.

XII.

The results of so many labors were not long in coming. The notion of geodesic curvature which Gauss already possessed, but without having published it, was given by Bonnet and Liouville, the theory of surfaces of which the radii of curvature are functions one of the other, inaugurated in Germany by two propositions which would figure without disadvantage in the memoir of Gauss, was enriched by Ribaucour, Halphen, S. Lie and others, with a multitude of propositions, some concerning these surfaces envisaged in a general manner; others applying to particular cases where the relation between the radii of curvature takes a form particularly simple; to minimal surfaces for example, and also to surfaces of constant curvature, positive or negative.

The minimal surfaces were the object of works which make of their study the most attractive chapter of infinitesimal geometry. The integration of their partial differential equation constitutes one of the most beautiful discoveries of Monge; but because of the imperfection of the theory of imaginaries, the great geometer could not get from its formulas any mode of generation of these surfaces, nor even any particular surface. We will not here retrace the detailed history which we have presented in our 'Leçons sur la théorie des surfaces'; but it is proper to recall the fundamental researches of Bonnet which have given us, in particular, the notion of *surfaces associated with a given surface,* the formulas of Weierstrass which establish a close bond between the minimal surfaces and the functions of a complex variable, the researches of Lie by which it was established that just the formulas of Monge can to-day serve as foundation for a fruitful study of minimal surfaces.

In seeking to determine the minimal surfaces of smallest classes or degrees, we were led to the notion of double minimal surfaces which is dependent on *Analysis situs.*

Three problems of unequal importance have been studied in this theory.

The first, relative to the determination of minimal surfaces inscribed along a given contour in a developable equally given, was solved by celebrated formulas which have led to a great number of propositions. For example, every straight traced on such a surface is an axis of symmetry.

The second, set by S. Lie, concerns the determination of all the algebraic minimal surfaces inscribed in an algebraic developable, without the curve of contact being given. It also has been entirely elucidated.

The third and the most difficult is what the physicists solve experimentally, by plunging a closed contour into a solution of glycerine. It concerns the determination of the minimal surface passing through a given contour.

The solution of this problem evidently surpasses the resources of geometry. Thanks to the resources of the highest analysis, it has been solved for particular contours in the celebrated memoir of Riemann and in the profound researches which have followed or accompanied this memoir.

For the most general contour, its study has been brilliantly begun, it will be continued by our successors.

After the minimal surfaces, the surfaces of constant curvature attracted the attention of geometers. An ingenious remark of Bonnet connects with each other the surfaces of which one or the other of the two curvatures, mean curvature or total curvature, is constant.

Bour announced that the partial differential equation of surfaces of constant curvature could be completely integrated. This result has not been recovered; it would seem even very doubtful if we consider a research where S. Lie has essayed in vain to apply a general method of integration of partial differential equations to the particular equation of surfaces of constant curvature.

But, if it is impossible to determine in finite terms all these surfaces, it has at least been possible to obtain certain of them, characterized by special properties, such as that of having their lines of curvature plane or spheric; and it has been shown, by employing a method which succeeds in many other problems, that from every surface of constant curvature may be derived an infinity of other surfaces of the same nature, by employing operations clearly defined which require only quadratures.

The theory of the deformation of surfaces in the sense of Gauss has been also much enriched. We owe to Minding and to Bour the detailed study of that special deformation of ruled surfaces which leaves the generators rectilineal. If we have not been able, as has

been said, to determine the surfaces applicable on the sphere, other surfaces of the second degree have been attacked with more success, and, in particular, the paraboloid of revolution.

The systematic study of the deformation of general surfaces of the second degree is already entered upon; it is one of those which will give shortly the most important results.

The theory of infinitesimal deformation constitutes to-day one of the most finished chapters of geometry. It is the first somewhat extended application of a general method which seems to have a great future.

Being given a system of differential or partial differential equations, suitable to determine a certain number of unknowns, it is advantageous to associate with it a system of equations which we have called *auxiliary system* and which determines the systems of solutions infinitely near any given system of solutions. The auxiliary system being necessarily linear, its employment in all researches gives precious light on the properties of the proposed system and on the possibility of obtaining its integration.

The theory of lines of curvature and of asymptotic lines has been notably extended. Not only have been determined these two series of lines for particular surfaces such as the tetrahedral surfaces of Lamé; but also, in developing Moutard's results relative to a particular class of linear partial differential equations of the second order, it proved possible to generalize all that had been obtained for surfaces with lines of curvature plane or spheric, in determining completely all the classes of surfaces for which could be solved the problem of *spheric representation.*

Just so has been solved the correlative problem relative to asymptotic lines in making known all the surfaces of which the infinitesimal deformation can be determined in finite terms. Here is a vast field for research whose exploration is scarcely begun.

The infinitesimal study of rectilinear congruences, already commenced long ago by Dupin, Bertrand, Hamilton, Kummer, has come to intermingle in all these researches. Ribaucour, who has taken in it a preponderant part, studied particular classes of rectilinear congruences and, in particular, the congruences called *isotropes,* which intervene in the happiest way in the study of minimal surfaces.

The triply orthogonal systems which Lamé used in mathematical physics have become the object of systematic researches. Cayley was the first to form the partial differential equation of the third order on which the general solution of this problem was made to depend.

The system of homofocal surfaces of the second degree has been generalized and has given birth to that theory of general *cyclides* in which may be employed at the same time the resources of metric

geometry, of projective geometry and of infinitesimal geometry. Many other orthogonal systems have been made known. Among these it is proper to signalize the *cyclic* sýstems of Ribaucour, for which one of the three families admits circles as orthogonal trajectories, and the more general systems for which these orthogonal trajectories are simply plane curves.

The systematic employment of imaginaries, which we must be careful not to exclude from geometry, has permitted the connection of all these determinations with the study of the finite deformation of a particular surface.

Among the methods which have permitted the establishment of all these results it is proper to note the systematic employment of linear partial differential equations of the second order and of systems formed of such equations. The most recent researches show that this employment is destined to renovate most of the theories.

Infinitesimal geometry could not neglect the study of the two fundamental problems set it by the calculus of variations.

The problem of the shortest path on a surface was the object of masterly studies by Jacobi and by Ossian Bonnet. The study of geodesic lines has been followed up; we have learned to determine them for new surfaces. The theory of ensembles has come to permit the following of these lines in their course on a given surface.

The solution of a problem relative to the representation of two surfaces one on the other has greatly increased the interest of discoveries of Jacobi and of Liouville relative to a particular class of surfaces of which the geodesic lines could be determined. The results concerning this particular case led to the examination of a new question: to investigate all the problems of the calculus of variations of which the solution is given by curves satisfying a given differential equation.

Finally, the methods of Jacobi have been extended to space of three dimensions and applied to the solution of a question which presented the greatest difficulties: the study of properties of minimum appertaining to the minimal surface passing through a given contour.

XIII.

Among the inventors who have contributed to the development of infinitesimal geometry, Sophus Lie distinguishes himself by many capital discoveries which place him in the first rank.

He was not one of those who show from infancy the most characteristic aptitudes, and at the moment of quitting the University of Christiania in 1865, he still hesitated between philology and mathematics.

It was the works of Pluecker which gave him for the first time full consciousness of his veritable calling.

He published in 1869 a first work on the interpretation of imaginaries in geometry, and from 1870 he was in possession of the directing ideas of his whole career. I had at this epoch the pleasure of seeing him often, of entertaining him at Paris, where he had come with his friend F. Klein.

A course by M. Sylow followed by Lie had revealed to him all the importance of the theory of substitutions; the two friends studied this theory in the great treatise of C. Jordan: they were fully conscious of the important rôle it was called on to play in so many branches of mathematical science where it had not yet been applied.

They have both had the good fortune to contribute by their works to impress upon mathematical studies the direction which to them appeared the best.

In 1870, Sophus Lie presented to the Academy of Sciences of Paris a discovery extremely interesting. Nothing bears less resemblance to a sphere than a straight line, and yet Lie had imagined a singular transformation which made a sphere correspond to a straight, and permitted, consequently, the connecting of every proposition relative to straights with a proposition relating to spheres and *vice versa.*

In this so curious method of transformation, each property relative to the lines of curvature of a surface furnishes a proposition relative to the asymptotic lines of the surface attained.

The name of Lie will remain attached to these deep-lying relations which join to one another the straight line and the sphere, those two essential and fundamental elements of geometric research. He developed them in a memoir full of new ideas which appeared in 1872.

The works which followed this brilliant début of Lie fully confirmed the hopes it had aroused. Pluecker's conception relative to the generation of space by straight lines, by curves or surfaces arbitrarily chosen, opens to the theory of algebraic forms a field which has not yet been explored, that Clebsch scarcely began to recognize and settle the boundaries of. But, from the side of infinitesimal geometry, this conception has been given its full value by Sophus Lie. The great Norwegian geometer was able to find in it first the notion of congruences and complexes of curves, and afterward that of *contact transformations* of which he had found, for the case of the plane, the first germ in Pluecker. The study of these transformations led him to perfect, at the same time with M. Mayer, the methods of integration which Jacobi had instituted for partial differential equations of the first order; but above all it threw the most brilliant light on the most difficult and the most obscure parts of the theories relative to partial differential equations of higher order. It permitted Lie, in particular, to indicate all the cases in which the method of characteristics of Monge is fully applicable to equations of the second order with two independent variables.

In continuing the study of these special transformations, Lie was led to construct progressively his masterly theory of continuous groups of transformations and to put in evidence the very important rôle that the notion of group plays in geometry. Among the essential elements of his researches, it is proper to signalize the infinitesimal transformations, of which the idea belongs exclusively to him.

Three great books published under his direction by able and devoted collaborators contain the essential part of his works and their applications to the theory of integration, to that of complex units and to the non-Euclidean geometry.

XIV.

By an indirect way I have arrived at that non-Euclidean geometry of which the study takes in the researches of geometers a place which grows greater each day.

If I were the only one to talk with you about geometry, I would take pleasure in recalling to you all that has been done on this subject since Euclid or at least from Legendre to our days.

Envisaged successively by the greatest geometers of the last century, the question has progressively enlarged.

It commenced with the celebrated *postulatum* relative to parallels; it ends with the totality of geometric axioms.

The 'Elements' of Euclid, which have withstood the action of so many centuries, will have at least the honor before ending of arousing a long series of works admirably enchained which will contribute, in the most effective way, to the progress of mathematics, at the same time that they furnish to the philosophers the points of departure the most precise and the most solid for the study of the origin and of the formation of our cognitions.

I am assured in advance that my distinguished collaborator will not forget, among the problems of the present time, this one, which is perhaps the most important, and with which he has occupied himself with so much success; and I leave to him the task of developing it with all the amplitude which it assuredly merits.

I have just spoken of the elements of geometry. They have received in the last hundred years extensions which must not be forgotten. The theory of polyhedrons has been enriched by the beautiful discoveries of Poinsot on the star polyhedrons and those of Moebius on polyhedrons with a single face. The methods of transformation have enlarged the exposition. We may say to-day that the first book contains the theory of translation and of symmetry, that the second amounts to the theory of rotation and of displacement, that the third rests on homothety and inversion. But it must be recognized that it is thanks to analysis that the 'Elements' have been enriched by their most beautiful propositions.

It is to the highest analysis we owe the inscription of regular polygons of 17 sides and analogous polygons. It is to it we owe the demonstrations so long sought, of the impossibility of the quadrature of the circle, of the impossibility of certain geometric constructions with the aid of the ruler and the compasses. It is to it finally that we owe the first rigorous demonstrations of the properties of maximum and of minimum of the sphere. It will appertain to geometry to enter upon this ground where analysis has preceded it.

What will be the elements of geometry in the course of the century which has just commenced? Will there be a single elementary book of geometry? It is perhaps America, with its schools free from all program and from all tradition, which will give us the best solution of this important and difficult question.

Von Staudt has sometimes been called the *Euclid of the nineteenth century;* I would prefer to call him the *Euclid of projective geometry;* but that geometry, however interesting it may be, is it destined to furnish the unique foundation of the future elements?

XV.

The moment has come to close this over-long recital, and yet there is a crowd of interesting researches that I have been, so to say, forced to neglect.

I should have loved to talk with you about those geometries of any number of dimensions of which the notion goes back to the first days of algebra, but of which the systematic study was commenced only sixty years ago by Cayley and by Cauchy. This kind of researches has found favor in your country and I need not recall that our illustrious president, after having shown himself the worthy successor of Laplace and Le Verrier, in a space which he considers with us as being endowed with three dimensions, has not disdained tō publish, in the *American Journal,* considerations of great interest on the geometries of n dimensions.

A single objection can be made to studies of this sort, and was already formulated by Poisson: the absence of all real foundation, of all *substratum* permitting the presentation, under aspects visible and in some sort palpable, of the results obtained.

The extension of the methods of descriptive geometry, and above all the employment of Pluecker's conceptions on the generation of space, will contribute to take away from this objection much of its force.

I would have liked to speak to you also of the method of equipollences, of which we find the germ in the posthumous works of Gauss, of Hamilton's quaternions, of Grassmann's methods and in general of systems of complex units, of the *Analysis situs,* so intimately connected with the theory of functions, of the geometry called *kinematic,*

of the theory of abaci, of geometrography, of the applications of geometry to natural philosophy or to the arts. But I fear, if I branched out beyond measure, some analyst, as has happened before, would accuse geometry of wishing to monopolize everything.

My admiration for analysis, grown so fruitful and so powerful in our time, would not permit me to conceive such a thought. But, if some reproach of this sort could be formulated to-day, it is not to geometry, it is to analysis it would be proper, I believe, to address it. The circle in which the mathematical studies appeared to be enclosed at the beginning of the nineteenth century has been broken on all sides.

The old problems present themselves to us under a new form, new problems offer themselves, whose study occupies legions of workers.

The number of those who cultivate pure geometry has become prodigiously restricted. Therein is a danger against which it is important to provide. We must not forget that, if analysis has acquired means of investigation which it lacked heretofore, it owes them in great part to the conceptions introduced by the geometers. Geometry must not remain in some sort entombed in its triumph. It is in its school we have learned: our successors must learn never to be blindly proud of methods too general, to envisage the questions in themselves and to find, in the conditions particular to each problem, perhaps a direct way towards a solution, perhaps the means of applying in an appropriate manner the general procedures which every science should gather.

As Chasles said at the beginning of the 'Aperçu historique': 'The doctrines of pure geometry offer often, and in a multitude of questions, that way simple and natural which, penetrating to the very source of the truths, lays bare the mysterious chain which binds them to each other and makes us know them individually in the way most luminous and most complete.'

Cultivate therefore geometry, which has its own advantages, without wishing, on all points, to make it equal to its rival.

For the rest, if we were tempted to neglect it, it would soon find in the applications of mathematics, as it did once before, means to rise up again and develop itself anew. It is like the giant Anteus who recovered his strength in touching the earth.

SOME PRESENT PROBLEMS IN TECHNICAL CHEMISTRY.*

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TECHNICAL chemistry may be regarded as the performance of a chemical reaction or series of reactions on a scale sufficiently large and by a method sufficiently economical to enable the product to be sold at a profit. The problems which confront the investigators in this field of endeavor may, therefore, be divided into two classes according as they pertain to the chemical reaction involved, or to the process to be employed in carrying on this reaction. The first division is pure chemistry, even though the results of the solution be utilitarian; the second is chemical engineering. Although in the program of this congress the utilitarian side of chemistry is widely separated from the subject of general chemistry, there is in reality no dividing line between the two. It would be difficult to find an investigator in the field of pure science who does not hope, and indeed believe, that the results of his labor will at some time prove of value to humanity; may ultimately be utilitarian. On the other hand, few if any chemical manufacturers would admit that in solving their chemical problems they do not utilize the most scientific methods at their command. The research assistant is in the last analysis utilitarian; while the successful chemical engineer is preeminently scientific.

Probably in no country have the problems confronting the chemical industries been so successfully met as in Germany; yet Germany does not excel in chemical engineers. Engineering enterprises—mechanical, civil and electrical, as well as chemical—are carried on as successfully in England and America as they are in Germany; and still the latter leads the world in her chemical manufactures. The explanation for this lies in the fact that Germany pays the greatest attention to the first class of problems, as above divided, and recognizes that pure chemistry is inseparably connected with her industries; that the application of new facts and principles follows rapidly when once these facts and principles are known. Most of the problems in technical chemistry are first considered problems in pure chemistry and studied in accordance with recognized methods of modern research by men fully trained in pure science. If these men are also chemical engineers, the

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ultimate solution of the problem is proportionately hastened; but they are first of all men trained in the spirit and methods of scientific research.

In general, an investigation may be prompted by either or both of two incentives; either by the pleasure to be derived from achievement and the love of scientific study for itself, or by the hope that from the investigation some immediately useful result may be obtained. Yet between the product of the first motive—pure chemistry—and the ultimate result of the second—technical chemistry—a difference does not necessarily exist. The fact that a piece of work is undertaken and carried on with the predetermined purpose of applying the results to a practical or commercial end does not in itself render it any the less a study in pure chemistry. The method of thought and action employed will be that of the investigator in pure science whatever the ultimate object may be. To make the result of the work an achievement in technical chemistry an important contribution must then be made by the chemical engineer, in order that the conditions making up the definition of the term 'technical chemistry' as already stated may be fulfilled.

In trying to point out, therefore, some of the important problems in technical chemistry, no attempt will be made to distinguish between the part which must first be played by pure chemistry in their solution, and that which will still remain to be done by the chemical engineer to make this contribution utilitarian.

There is always a tendency to measure the importance of a subject by the extent of one's knowledge of it and the depth of the interest one has in it. In order, therefore, that we may obtain a proper perspective, we must consider a problem important in proportion as it affects the greatest number of people; of moment according as the results of its solution will be far-reaching in their effects, or be but of local benefit.

From this point of view, the first industry to demand attention is the manufacture of fertilizers. In the last ten years the product of this industry in the United States alone has increased from 1,900,000 tons to 2,900,000 tons, an increase of over 50 per cent. This increase is probably more marked in America than in the older countries of Europe, because the necessity of replenishing the virgin soil was there reached long ago, while with us it is only begun. The magnitude of the industries which are dependent directly or indirectly upon agricultural products is so well recognized that it needs no discussion here. That the supply of crude material from which plant life derives its nourishment should be maintained is therefore a source of responsibility for the present as well as for future generations. Of this as of every great industry it may be said that the supply of raw material for to-morrow is a problem for to-day.

Dr. H. W. Wiley, of the U. S. Department of Agriculture, has pointed out the surprisingly large amount of potash, phosphoric acid and nitrogen which is yearly taken up by the agricultural crops alone. The average percentage of ash in all the important crops has been accurately determined and their percentage composition in respect to potash and phosphoric acid is known. In addition to this we have a satisfactory knowledge of the percentage of albuminous matter contained in the more important agricultural products. From these figures and the reports of the U. S. Department of Agriculture we can calculate the amount of potash, phosphoric acid and nitrogen consumed each year. Allowing a value of four cents a pound for potash, five cents for phosphoric acid and twelve cents for nitrogen, the total value of these ingredients for a single year amounts to the enormous sum of $3,200,000,000. To be sure, this is not all removed from the farm and lost to the soil; but that which remains in the form of straw and manure is but a small percentage of the whole. Straw is generally burned, while the soluble salts of the manure heaps are often allowed to leach out and go to waste. When, in addition, we consider the terrible waste involved in the modern methods of sewage disposal, where, instead of being returned to the soil, these valuable constituents are carried to the ocean, the net loss of these chemicals can be easily appreciated.

Of these three most important ingredients making up a fertilizer for general purposes, phosphoric acid alone seems to be at hand in practically inexhaustible quantities. Slag rich in phosphoric acid from certain metallurgical processes is already much used as a source of this material. Fresh deposits of phosphate rock of such enormous extent are being brought to light almost every day that our supply of this material may give us little immediate concern.

Although the Strassfurt region of Germany may continue to ship undiminished quantities of potash salts, the second important ingredient of a fertilizer, the world's supply can not be said to be on a perfectly satisfactory basis until independent sources are developed. In the year 1902 the value of the potash salts imported into the United States amounted to four and a half million dollars. The recovery of potash from wood ashes, while once an important industry, must diminish as the value of hard wood increases. While there are doubtless natural beds of potassium salt still to be discovered, the time seems rapidly approaching when we should render more readily available the great amount of potassium distributed throughout the mineral kingdom. Rhodin had already accomplished much towards this end when he showed that feldspar could be made to yield the greater part of its potash when it was heated with lime and common salt. Clark has found that when the mineral leucite with its 21 per cent. potassium

oxide is heated with ammonium chloride, the potassium is converted into chloride and is easily separated from the melt. If this reaction could be extended to orthoclase and the ammonia recovered by treatment with lime, the enormous quantity of potash contained in this mineral would be at our service.

It is, however, to the supply of available nitrogen that the greatest importance attaches. The sodium nitrate producing countries of South America exported last year 1,300,000 tons, a large percentage of which came to America. Egypt and the southwestern United States have nitrate deposits, but of their extent and value little is as yet known. Of the other form of available nitrogen, ammonia, our main supply is at present from the destructive distillation of coal. Although the introduction of by-product coke ovens has increased this supply, our domestic production is now not over 40,000 tons a year.

In the atmosphere, however, we have a never-failing source of nitrogen which needs only to be converted into other forms to be of the greatest value. It is interesting to note that even as long ago as 1840 this same problem was the subject of considerable experimentation and the basis of several technical processes. In this year there was erected in France a plant for the manufacture of potassium ferrocyanide which depended on the atmosphere for the supply of nitrogen, and which at one time turned out almost a ton of product per day. From this time until the present, the utilization of this inexpensive and inexhaustible supply of raw material has been an attractive field and has held the attention of many investigators. It had long been known that while carbon and nitrogen alone could not be made to unite, the union was effected when these elements were brought together in the presence of a strong alkali. The technical difficulties in the way of successfully applying this reaction seem to have been the rapid destruction of the retorts and the loss of alkali through volatilization. With the advent of cheap electricity and the consequent development of the electric furnace, this idea was made the basis of further work. The destruction of the retorts was largely overcome by generating the heat within the apparatus rather than without. When a non-volatile alkali was used to eliminate the loss from this source and a higher temperature maintained, it was found that a carbide was formed as an intermediate product and that nitrogen readily reacted with the carbon thus held in combination.

Among the investigators who have thus far taken advantage of this reaction may be mentioned the Ampere Chemical Company, located at Niagara Falls, and the group of men represented by the Siemens and Halske Company, of Berlin. The former first produces a carbide of barium and then converts it into barium cyanide by passing over it air from which the oxygen has either been removed or converted into

carbon monoxide. Robert Bunsen long ago showed that by using steam the nitrogen in an alkaline cyanide may be converted into ammonia. In this case barium oxide would be left to be returned to the furnace and to continue the cycle. When advantage is taken of the process discovered by Professor Ostwald, by which ammonia is converted into nitric acid through the medium of a catalyzing or contact agent, the production of nitrates by way of the cyanide reaction is easily foreseen.

The Siemens and Halske Company prepared in addition to cyanide and ammonia by use of the carbide-nitrogen reaction a new compound in technical chemistry, calcium cyanamide. In contradistinction to cyanides the nitrogen of this compound is available for plant food and can take the place of the more common nitrogen salts in commercial fertilizers. The technical difficulties in the way of the economic application of these processes are doubtless very great, but when one considers the advance which has been made in the last five years he has ample reasons to believe that it will not be a great while before the synthetic preparation of the cyanides, ammonia and nitric acid from atmospheric nitrogen will be on a commercial basis.

The old reaction by which nitrogen and oxygen were made to unite through the agency of a high potential electric discharge has been made the basis of a process for the manufacture of nitric acid by the Atmospheric Products Company, operating at Niagara Falls. For agricultural purposes it is proposed to absorb the nitric acid thus formed in milk of lime and so produce an exceptionally cheap product. There still remains much to be done before this can be called a technical process.

A very much less technical, but so far as our knowledge at present goes, a more promising method of fixing atmospheric nitrogen in the form of nitrates, is through the agency of bacteria. While it is true that one group of bacteria has the power of breaking down nitrates with the production of nitrogen gas, there are other groups which are equally able to absorb elementary nitrogen with the production of nitrates. A great deal of excellent work has recently been done by the U. S. Department of Agriculture, with the result that cultures for the artificial inoculation of the soil may now be obtained in considerable quantity. It has been found that these bacteria when grown upon nitrogen-free media may be dried without losing their high activity. When immersed in water they are easily revived. A dry culture similar to a yeast-cake and of about the same size can thus be sent out and used to prepare a fluid in which the original nitrogen fixing bacteria may be multiplied sufficiently to inoculate a number of acres of land. The amount of material thus obtained is limited only by the quantity of the nutrient water solution used in increasing the

germs. Field experiments have shown the wonderful activity of these bacteria in fixing atmospheric nitrogen and the splendid crops which may be grown upon what would otherwise be almost sterile soil.

In this one problem of our future supply of available nitrogen for agriculture as well as general manufacturing purposes, we note the aid which technical chemistry draws from the other departments of natural science. The electrical engineer and the biologist have already contributed a great share to its solution. There remains, however, no small amount of work for the technical chemist to perform before the desired end is reached.

In an address on 'Chemical Problems of To-day,' delivered by Victor Meyer in 1889, the author pointed out that, although the synthesis of starch from carbon dioxide and water was a result not to be expected in the near future, yet, he says, 'we may reasonably hope that chemistry will teach us to make the fiber of wood the source of human food.' While we do not consider that this is a problem of technical chemistry for the present, the possible use of cellulose as a raw material from which to make food renders more acute a problem which is to-day clamoring for solution, namely, the preservation of our forests. The influence which the forests of a country have upon its civilization is a topic which has been much discussed of late. That there is an intimate relation between the woodland of a district and the regularity of its rainfall, the absence of floods and freshets and the general climatic conditions, there seems now to be little doubt. But the consumption of forest products continues to increase far out of proportion to the growth of new timber. The substitution of other raw material in chemical industries which now use wood for this purpose becomes therefore an economic problem for the solution of which the chemist is held responsible.

The production of cellulose from raw materials other than wood is the first important factor in the chemical side of the question. The weight of wood consumed for the production of chemical fiber for the year 1902 was something over two million tons, while one and a half million tons were used for the manufacture of ground wood pulp. While from some points of view our American forests are sufficient to supply the demand for many years to come, it does not excuse us for the terrible waste of cellulose in forms other than wood which we are constantly suffering.

On our flax fields of the west we are annually burning thousands of tons of flax straw which contains a large percentage of cellulose in a most valuable form. Considerable work has already been done on the utilization of this straw in the production of fiber and some success has met the efforts of the By-Products Paper Company now located at Niagara Falls. There is, however, still much room for improve-

ments. In the straw of our wheat and oats crops, which is to-day largely destroyed on the fields, we have another source of cellulose of which we avail ourselves but little. In Europe the production of straw fiber is carried on to some extent, but is capable of great extension should sufficient economy in the process for treating it be introduced. The high content of silica has ever been a source of loss, owing to the fact that the formation of sodium silicate prevents the recovery of the soda now used in the digestion of the straw.

By far the greatest loss of valuable cellulose, however, is found in waste cornstalks and in bagasse, or in the sugar-cane after the soluble portions have been removed. There is a close analogy between these two products in that there is associated with the woody portion carrying the cellulose a large amount of non-usable pith. Rapid progress has been made in the utilization of both of these raw materials within the last few years, and the indications are that before long they will prove a source of value rather than a nuisance as is frequently the case at present. The market price of bleached cellulose fiber is to-day from two and a half to three and a half cents per pound. Starch may be bought for from two and a half to four cents, according to its source. It is seen, therefore, that there is little manufacturing margin in the conversion of cellulose into starch or sugar until the cost of the former has been considerably reduced. This can come about only through new processes designed to operate more economically than those at present in use and to use as raw products the cellulose at present wasted on the fields.

It would seem that a more economical step towards the production of food from wood might be through its ligneous or non-cellulose constituents. For every ton of cellulose produced there must be used two tons of wood; that is, an equal weight is wasted. In the soda process as now conducted these non-cellulose materials are burned to recover the soda which is held in combination with them. In the sulphite process this enormous amount of material, aggregating for America alone in a single year almost one million tons, finds its way into the water courses and ultimately to the ocean. This organic matter is most complex in its composition, but consists largely of one class of substances closely allied to the sugars, and another class having the general characteristics of tannins. That these sugar like substances could be made to yield a food material is from their nature quite possible; so far as we know, however, but little has been accomplished in this direction. A number of uses have from time to time been proposed for this waste, but as yet none has been of practical value. Among the more promising may be mentioned a *preparation* to be used in tanning leather, a sizing material for paper and a substitute for dextrine in calico printing and as an adhesive.

In addition to our annual supply of 4,000,000 tons of paper stock, we depend upon the forests for our supply of acetic acid, methyl alcohol and acetone. In countries where there is not the exorbitant tax upon fermented mash that exists in the United States there would seem to be an opening for a process for the production of acetic acid from alcohol in a more concentrated form than can be produced through the aid of *mycoderma aceti*. It would, it is true, in the end depend upon the supply of fermentative material; but there are being wasted every year in the semi-tropical countries many thousand tons of crude molasses that could thus serve an economic end. For many uses acetic acid may be displaced by formic acid, a compound which admits of synthesis from carbon and water. The farther this substitution is carried the more acetic acid will be available for the manufacture of acetone and other compounds where the acetyl group is a necessity.

Concurrent with the disappearing forests is the increasing scarcity of vegetable tanning material. Hemlock and oak bark, sumac and chestnut wood are still the most important sources of tannins, although quebracho from South America and canaigre from Mexico and Texas are daily playing a more important part. The introduction of chrome tannage for upper leathers had a marked influence upon this industry inasmuch as it furnished a cheap substitute for those finer tanning materials which were constantly increasing in price. A mineral tannage for heavy hides, along the lines so successfully followed for upper leather has, however, not been developed; the product lacks the rigidity and firmness combined with the flexibility which is characteristic of oak or hemlock tanned leather. There must exist methods for supplying to the hide, materials having an action analogous to these vegetable tannins; it remains but to seek them out in order that a new and profitable industry may be established.

It is thus seen that technical chemistry can do much for the conservation of our forests; along many lines the time for action has already come.

When the consumption of a given article is in excess of its supply the market price must rise. In accordance with this law we have seen the price of crude India rubber more than double in the last few years. The consumer of the finished article must pay this advance or accept an inferior grade of goods. Generally he does both.

The tropical forests of Africa and South America still contain untold quantities of India rubber; but so does sea water contain gold. For manufacturing purposes both might as well not exist. The only human beings that can live under the conditions obtaining in these tropical jungles are the natives; but the distance to which the natives can transport the rubber is comparatively limited. Although rubber-

bearing trees are now being cultivated in the more easily inhabitable portions of the tropics, it will be a long time before this source of supply is an important factor in the market. And thus it comes that the synthesis of india rubber presents to-day, from at least the technical side, one of the most promising problems in chemistry.

The investigation of india rubber is greatly handicapped by the fact that it exists only in the colloidal state. The difficulties are perhaps more largely physical than chemical; that is, it is the molecular aggregation rather than the atomic structure of the individual molecule which presents such almost insurmountable difficulties. There are no clearly defined melting points, boiling points, tendencies to crystallize or any of those means of separating mixtures or characterizing individuals which aid in the investigation of most organic compounds. The researches of Weber and Harris, resulting in the establishment of the much needed methods of analysis, have been of incalculable advantage to all those working with either the raw or the manufactured article. In many directions also the paths along which important results are to be obtained have already been blazed by these investigators. Probably no other field presents such difficulties of manipulation in addition to such profound problems of organic chemistry as does the investigation of india rubber; but on the other hand few such unlimited opportunities for valuable work are offered in the field of chemical research.

Under the general head of utilization of trade wastes may be considered a large number of technical problems the solution of which would not only add wonderfully to the economic resources of the country, but would aid in the solution of that much vexed question, river pollution. We have already mentioned the soda and sulphite liquor resulting from the manufacture of cellulose fiber from wood. Of almost equal importance is the waste yeast which is daily produced in the brewing of beer and ale. An extract of this yeast has a food value as shown by analysis equal to the best meat extracts. As the quantity of yeast allowed to go to waste is from one to two pounds for every barrel of beer brewed, we can form estimates of the great amount of this material at hand. Arsenic sulphide from the purification of crude acids, grease from the washing of wool, the utilization of city garbage and many other problems of this order are everywhere in evidence. It is not within the compass of this discussion to mention these almost innumerable sources of manufacturing waste which exist in the chemical industry; but keen competition on the one hand and the state boards of health on the other are constant stimuli to increased effort towards their utilization.

Although I have endeavored to select the above examples of unsolved problems with a view to touching upon as large a portion of

the field of technical chemistry as possible, I could doubtless with equal propriety have selected others. We can simply mention such important questions as the hygienic preservation of food, the flame-proofing and preservation of wood, prevention of the corrosion of structural iron and steel, the great problems of chemical metallurgy, et cetera. We must, however, note some of the more recently developed forces and phenomena of nature, the application of which to technical chemistry forms problems for to-day. One of the most important of these is electricity. Thanks to the triumphs of modern electrical engineering we are now able to call to our aid unlimited amounts of this agent at a cost comparable to that of other forms of energy. Possibly the simplest, though not the earliest, method of utilizing electrical energy in chemical processes is in supplying the heat necessary to carry on a reaction directly at the point where the reaction takes place. In a number of chemical industries, for example, the manufacture of phosphorus, it was previously necessary to produce within thick walled retorts a very high temperature. The result was that a great deal of heat was wasted, the retorts deteriorated very rapidly and the reaction was carried on at a low efficiency. By using an electric furnace for the manufacture of phosphorus these expensive retorts are eliminated. In addition much cheaper raw materials may be used, the process is made continuous and a high efficiency obtained. By the substitution of electrical heating for the closed retorts previously used in the preparation of carbon bisulphide the manufacture of this chemical has been placed upon an entirely new basis. The economy introduced by supplying the heat at the point where the union of carbon and sulphur takes place is clearly indicated by the low price at which this material can now be sold and its enormously increased consumption.

With the ability to obtain temperatures far above that which is possible by the ordinary combustion of fuel there was opened up a new field in synthetic chemistry. Reactions which it was impossible to carry out on a technical scale and others the existence of which was not suspected are now through the application of electrical energy become the bases of large manufacturing enterprises. Calcium carbide, carborundum, artificial graphite and many hitherto unknown alloys are the commercial products of the electric furnace where temperatures in the neighborhood of 3000° C. obtain.

The third and more strictly chemical application of electrical energy is in the use of the current for electrolysis. Faraday long ago determined the laws according to which chemical compounds break up when subjected to the passage of an electric current. It is only in recent years, however, that the cost of electrical energy has made it possible to apply the knowledge thus furnished by this great in-

vestigator. Among the many important advances due to this use of electricity may be mentioned the manufacture of caustic soda and bleaching powder by the electrolysis of brine. The percentage of the world's supply of these two standard articles which is now made by this process is already a formidable figure and constantly increasing. In the electrolytic production of aluminum we have seen an entirely new industry develop until it is now one of magnificent proportions.

What the application of the electricity will do for technical chemistry in the future can be predicted only by estimating the results of the past. In many fields it is practically virgin soil over which only the pioneers have trod, and which is still waiting to be tilled.

Under the name of catalysis or contact action is included the other force that we can mention this afternoon, the usefulness of which the technical chemist is only beginning to appreciate.

These substances which are capable of so wonderfully increasing or decreasing the speed of a reaction without themselves appearing in its final products vary in their nature from such simple ones as metallic platinum or ferric oxide to the most delicately constituted ferments or enzymes. The manufacture of concentrated sulphuric acid by such a process is perhaps the most striking example of the application of this idea, although to be sure the finely divided platinum used at present plays but the rôle which the oxides of nitrogen have done so successfully in the past. The reproduction of photographic negatives by substituting for the action of light on sensitized paper the contact action of certain chemical compounds, is a process worthy of its distinguished discoverer, Professor Ostwald. For this application of the catalysis idea even the most pessimistic must prophesy a great future. Still another phase of this question is found in the hydrolysis of fats by the enzyme found in the seeds of the castor-oil plant. Instead of the application of acid, heat and pressure the same result is obtained at room temperature by the quiet action of this catalytic body. The advantages to be reaped by the development of these phenomena can scarcely be foreseen. Even the wildest dreamer might easily do injustice to the possibilities of this wonderful agent when intelligently used by the technical chemist.

We probably should not invite criticism were we to state that wherever we find a manufacturing establishment based upon chemical processes, there also exist problems in technical chemistry. That one factor which is so apparent that it scarcely needs mentioning, namely, the increase in the yield of processes now in operation, is enough to substantiate this assertion. The paramount question before us is, therefore, how can these problems best be solved. In any answer to this question there are two factors, both of which deeply affect the future growth of chemical industry. The first is the attitude of the

manufacturer towards science and scientific work; the second is the training of the coming chemist.

When, a few years ago, England awakened to the fact that many industries in which she was the pioneer and at one time the leader were in the main passing to other countries, there went up a great cry for 'technical education.' The nature of the industrial stimulus which has borne such magnificent fruit in Germany was not understood. In the minds of many, a panacea for all their difficulties was to be found in the technical education of the working classes. But this is unquestionably a mistake. Until there is a love of science for its own sake and an appreciation of the value of scientific methods among the leaders of chemical industry, the fruits of technical education can not be reaped. Carl Otto Weber, speaking of this move towards a more general scientific education in England, says "Until the nation as a whole recognizes that the prosecution of scientific study as a mere means of money making is a profanation defeating its own end, the history of industrial development in England will afford the same melancholy spectacle in this, as in the last century, technical education notwithstanding."

The time is past when a factory can be run by rule of thumb; when the chemist is looked down upon simply as a testing machine to be kept at a distance and generally mistrusted. It is true that there are many men to-day who pass under the name of chemist who are little more than testing machines; men who possess the ability to do nothing more than the most strictly routine analysis; but such men will never solve the technical problems of the present or any other time. I would not impugn the dignity or intrinsic value of analytical work—it is the corner stone of all chemical investigation. But I would emphasize the fact, for it is a fact, that the manufacturer who employs a so-called chemist, one trained to 'do' coppers or carbons or acids, and who at the same time expects this chemist to improve his process and keep his business in the skirmish line of the industrial battle, must eventually be numbered among the 'not accounted for.'

The second factor in this answer is the training of the coming chemist. What is the reply to that now so oft repeated question, What is the best preparation for a technical chemist? I am personally of the opinion that it is not to be found in the teaching of applied chemistry, as this term is generally understood. This training must provide for something more than simply copying the present—doing as well as others do; we must build for the future. We must provide men who are prepared to solve the unsolved problems. Within the last few months much has been said and written in America about the lack of adequate instruction in technical chemistry in our universities and colleges. It is assumed that American industries based on

chemical processes do not flourish for lack of men trained in this branch of science. This, however, is not the case. It is not more instruction in applied chemistry that America needs, but rather a deeper and broader knowledge of pure chemistry, with a more extended training in original research.

In many of the problems we have already noticed, the solution depends upon the discovery of new compounds—the investigation and study of new reactions and relationships. This is the province of pure organic and inorganic chemistry. The foundations of these two departments can not be too firmly or too broadly laid. The method of attack best followed in each can not be too well understood. But it is not sufficient that we study only the initial and the final products. It is all important to learn the influence of the variable factors on the process; to study the reaction for itself. This is the province of physical chemistry, a department of science the importance of which to technical chemistry can not be overestimated. To be able to actually apply the laws of chemistry and to predict the course of reactions from general principles already proven is a tremendous economy of both time and energy.

After we have acquired the tools, however, we must learn to use them; after we possess a sound knowledge of inorganic, organic and physical chemistry, we must have adequate training in work requiring original and independent thought.

As I have already noted, the training to be derived from an investigation may be the same even though the incentive for its undertaking may be different. While I believe that so far as possible the student should be influenced to work for the love of knowledge and for the mastery of science for itself, yet especially in his later years of study there are advantages in allowing him to combine with this a utilitarian aim. In America at least most men enter our technical schools with the intention of fitting themselves as rapidly as possible for some useful calling in life. They have a feverish desire to get through and to enter the creative industries and accomplish something. They will work with enthusiasm upon whatever they can be made to recognize as contributing to this end, but by their very directness are intolerant of supposed digressions from their chosen path. The presence of too much of this spirit is to be regretted; but it is a power to be turned to service, not to be opposed. It does not follow that for a training in scientific method and for broadening the mental horizon a research which can have little if any practical value is superior to one the solution of which can find immediate application. For advanced work as much pure organic chemistry, for example, can be learned from an attempt to convert safrol into eugenol (a consummation in itself devoutly to be wished) as in the transformation of

some other compound with a much longer name but with no higher destiny than to fill a place in Beilstein.

So also in physical chemistry. A careful, painstaking investigation of some of our already established industrial processes with a view to determining the maximum yield at the minimum cost is of the greatest educational value. In other words, a problem for research may have a distinctly practical bearing without being any the less a study in pure science, or without having thereby an inferior educational value.

In other problems we have noted, the solution largely depends upon the process, not the reaction. This demands the chemical engineer, a man who combines a broad knowledge of general chemistry with the essentials of mechanical engineering. He must be well schooled in the economics of chemistry; have a knowledge of the strength and chemical resistance of materials; be able to design and operate the mechanical means for carrying out on a commercial scale the reactions discovered, and duplicating the conditions already determined.

With men whose foundations are thus broadly and deeply laid, anxious to enter the industrial arena, and with a generous appreciation of the scientific man on the part of the manufacturer, coupled with a willingness to grant him an adequate return on the money invested in such an education, the problems in technical chemistry of the present must rapidly become the achievements of the past.

STAMINA.*

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ANALYSIS of vital statistics for the last three-quarters of a century shows an average increase in the duration of human life among civilized peoples from 42.2 years to 48.5 years. The chief increase has been during the latter half of that period, and, for the most part, by the reduced mortality from zymotic diseases, but, above all, from pulmonary tuberculosis, from which the reduction of mortality has been nearly fifty per cent.

Inquiry with regard to the means by which this reduction has been effected, shows it to have been almost wholly by sanitary efforts; by dealing with and destroying unsanitary surroundings, soil-drainage, purifying water supplies, reporting and restricting communicable diseases, sanitary supervision of schools, the destruction of sputum—the now everywhere recognized fountain-head from which the army of bacilli is perpetually reinforced—abolishment of cellar-dwellings, diminished overcrowding, cleanliness, disinfection, isolation and aeration; improved tenements, opened-up and wider streets, public parks and recreation grounds and establishment of sanitaria. This catalogue of sanitary efforts might be still further extended, though altogether without record of special effort for improved nutrition except for nursing infants.

Communicable as all competent observers know tuberculosis to be, while they equally well know that it is not so under all circumstances, it is indeed questionable whether any one of sound constitution and well nourished has ever contracted the disease from nursing consumptives, or from living with them otherwise, under good hygienic surroundings.

On the contrary, no matter how healthful the surroundings or the salubrity of the atmosphere, for poorly nourished and feeble persons, from whatever cause, there is no immunity from tuberculosis. For no one who even approximately comprehends the universality of microbic life—and of none more than tubercle bacilli—can fail to perceive that, however much we may be able to modify the external relations bearing upon liability to tuberculosis, nevertheless every indi-

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* Read at the International Congress on Tuberculosis, St. Louis, Mo., October 3, 1904.

vidual, no matter where his dwelling place, is more or less subject to tubercle bacilli; for, besides the utmost restriction of their prevalence by sanitary effort, unless the individual is possessed by an organism sufficiently fortified to resist and overcome conflict with them—for the conflict is certain everywhere—he is liable to contract tuberculosis. Hence it is that about one quarter of all the deaths recorded of mankind during adult life, is caused by tuberculosis, and nearly one half of the entire population, at some time in life, acquires the disease.

Tubercle bacilli are, indeed, abroad everywhere, a constant menace and challenge to one's power of resistance. Every intelligent person knows that the power of resisting the ordinary exciting causes of illness, such as sudden changes of temperature, exposure to damp soil, room or sheets, or night air with the windows closed, depends upon one's state of health. The power of resisting tubercle bacilli is no exception.

Health fortified by such conditions as the organism depends upon for its fabrication and maintenance opposes itself to all exciting causes of disease by the relative integrity, strength and vigor of all the organs and functions of the body. A person thus equipped, if beset by tubercle bacilli or other microbes, effectually resists them, devours them by oxidation and casts them off.

Feebleness, on the contrary, though not always appreciated, and sometimes cultivated, indeed, by the practise of that altogether too popular fad, abstemiousness, is always and everywhere a prevailing 'predisposition' to disease; and, associated as it commonly is with inadequate nourishment, it is the most frequent of all incitants to tuberculosis. Abstemiousness, however, is variable in its practise, and uncertain; one may over-eat and yet abstain from some essential food necessary for the maintenance of health. Adequate nourishment and stamina depend upon the supply of nutriment in the kinds and proportions required by our bodies. Food is required for a two-fold purpose; (1) to supply material for the construction and repair of tissue, and (2) to supply fuel for its maintenance, the production of heat and energy.

It is not necessary to our present purpose to pursue the subject of the origin and nature of food in its general sense, but to emphasize the importance of the essential elements of food comprehended in the various organic and inorganic compounds of which food consists, as follows: Carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorin, iodin, potassium, calcium, magnesium, sodium and iron.

It is not by any means necessary that a food should yield all these elements, indeed there is but one such food—milk—that is complete in this respect, and perfect, upon which the young of all mammalian animals are, or should be, for a time exclusively nourished. Neither

is it essential next following the period of nursing, that every food should be broken up, or 'refined' to facilitate its assimmilation and combinations in the structures of the body, since the functions of the organism are adapted to these processes.

Unfortunately for the infant, however, it frequently happens that after weaning, and if it has been nursed by a healthy mother, or other wet nurse, being well fed on two or three pints of wholesome milk, daily, its food supply is reduced by substitution of one kind or another, more or less devoid of essential elements, with the common result of emaciation and tenderness, and increased liability to sickness. Moreover, as said by Dr. William H. Maxwell, Superintendent of Public Schools of New York City and president of the National Educational Association, in his address at the International Congress of Arts and Science, September 23, 1904:

> Education, whether physical or mental, is seriously retarded, if not practically impossible, when the body is improperly or imperfectly nourished. The child of poverty, with body emaciated, blood thin and nerves on edge, because he has not enough to eat, grows up stunted in body and in mind.
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> What a farce it is to talk of schools providing equal opportunities for all when there are hundreds of thousands of children in our city schools who can not learn because they are always hungry!
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> The schools of Paris provide a simple, wholesome midday meal for their hungry children. In many places in the British Islands the same thing is being done. Should we do less in the cities of democratic America? In no other way can we be sure that the schools will, as far as education may, provide equal opportunities for all.

With regard to certain infectious diseases to which children are especially liable, in part, doubtless, because of their greater functional activity, but chiefly because their power of resistance has not yet become sufficiently fortified—for it is well known that adults generally who have not encountered those diseases in childhood rarely contract them subsequently—the same relative immunity exists; the strong and vigorous child is much less likely to contract them than the feeble; and the convalescent, those who are particularly feeble from any one of such diseases, are well known to be the most of all liable to attack and to succumb from another. And of pulmonary consumption, the most prevalent and the most fatal of all diseases, who does not know that enfeeblement invites it? That individuals are less and less liable to it—whether traceable to hereditary taint or otherwise—in proportion as coddling has been avoided, appetite for wholesome fat food cultivated, cold bathing habitual, protective but loose clothing worn, and exercise in the open air unrestrained? By the maintenance of these conditions all the processes of healthy organization are promoted and the constitution fortified against tubercle bacilli, as, in like manner, against other disease germs, no matter whence the quarter or at

whatever the age of the individual exposed; and no less against diseases not attributable to germs—and the more if we accept Metschnikoff's theory of the office of the *leucocytes* or white blood corpuscles, for these in both number and strength depend upon proper nourishment. 'In health,' says Kirke, 'the proportion of white to red corpuscles, which, taking an average, is about 1 to 500 or 600, varies considerably, even in the course of the same day. The variations appear to depend chiefly on the amount and probably also on the kind of food taken, the number of leucocytes being very considerably increased by a meal, and diminished again on fasting. Also in young persons, during pregnancy, and after great loss of blood, there is a large proportion of colorless blood corpuscles, which probably shows that they are more rapidly formed under these circumstances. In old age, on the other hand, their proportion is diminished.'*

No good observer will fail to recognize the coincidence of the condition which diminishes the proportion of leucocytes and the increased liability to disease—that of fasting; or note the no less remarkable coincidence, the diminution in the number of leucocytes and increasing infirmity of old age.

Foods are ordinarily divided into four classes: (1) Nitrogenous or albuminous substances; (2) fats or hydrocarbons; (3) carbohydrates, chiefly starchy substances and sugar; (4) mineral substances—water and salts.

The average daily amount of food required and of the different kinds, as comprehended in this classification, severally, varies considerably with individual conditions of age, size, exercise, circulation, activity of the eliminating organs, etc. The range in different male adults is from 34 to 46 ounces of so-called solid food, and from 70 to 90 ounces of water in some form, taken with and without solid food. For adult females, the average is from 3 to 5 ounces less. For children and youths, proportionally, more in the inverse ratio to age, 0.8 to 0.6 ounces for each pound weight of the body.

If individuals are undergoing great exertion they require more food, and, if they can obtain it, the needful increase is especially in the nitrogenous and fat foods.

> Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electric action, etc.) is nitrogenous. The nerves, the muscles, the gland-cells, the floating cells in the various liquids, the semen, and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen in order that these actions shall be performed; and the same constancy of the presence of nitrogen, where function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. (Parkes.)

* Kirke's 'Hand-Book of Physiology,' Vol. I., p. 79.

The average daily quantity of fat required by an adult to keep up healthy nutrition, according to various estimates, is two ounces, and proportionally more during the period of growth, after weaning—from half an ounce to two ounces.

1. A supply of fat, *per se*, to the blood is essential for histogenesis and for the protection of the tissues, and is also of importance for general use as a source of heat and mechanical force.

2. The carbo-hydrates and albuminoids may supply heat and mechanical force, but they can not take the place of fat in histogenesis and protection of tissue.

3. Fats may be supplied by absorption into the portal system, by absorption into the general lymphatic system, and by absorption into the lacteal system. But the latter is the means by which the principal supply of solid fat is carried into the blood, and is the most important.

4. The mean consumption of oxygen by an adult man of average stature (weight, 150 lbs.), taking ordinary exercise, is about thirty ounces in the twenty-four hours, and the heat evolved by each ounce of oxygen in combining with carbon, hydrogen, etc., is about 350 British units. Hence, 10,000 British units of heat will be evolved every twenty-four hours by the combination of thirty ounces of oxygen with carbon, hydrogen, etc.; therefore, the food of an ordinary adult man under ordinary circumstances, should be such as may, in addition to other purposes, evolve at least 10,000 British units of heat.

5. Practical experience in the dieting of large numbers of men, and other means, have enabled us to establish the fact that such an average man as I have spoken of requires for the maintenance of health, a diet which shall contain about four ounces of plastic material, three ounces of fat and ten ounces of carbohydrates; and, on careful analysis of this diet, we find that it can supply the required 10,000 British units of heat, viz., 2,516 from the plastic, 3,357 from the fat and 4,150 from the carbohydrates, total, 10,023.*

Fat, as an article of diet, furnishes the potential force necessary for the conversion of other food material into organic tissue and to maintain the bodily functions.

Professor W. O. Atwater, in one of his most important contributions to the Department of Agriculture,† on the nutritive value of foods, in comparing nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, states that 'a pound of protein lean meat or albumen of egg is just about equivalent to a pound of sugar or starch, and a little over two pounds of either would be required to equal one pound of the fat of meat or butter.'

The mistake commonly made with reference to the use of fat food is, that it is only, or especially, applicable to cold climates—an erroneous inference, the same as that cold is preventive of tuberculosis. That fat is the almost exclusive food in Arctic regions is because other food is not obtainable, not because of the frigid climate. It is necessary food, though not in such excess, at all times and every-

* 'Loss of Weight, Blood-spitting and Lung Diseases,' Horace Dobell, M.D.

† Farmer's Bulletin, No. 23, 1894.

where, to supply the potential energy required by the organism to construct the tissues and maintain the body, the temperature of the body being about the same in all climates. Fat does not stand alone in this regard, except under such extraordinary circumstances as those referred to. Carbohydrates of various kinds contribute to the same functions as fat, under ordinary conditions, but they do not suffice to maintain the stamina of the organism to the highest degree anywhere without the assistance of, or being supplemented by, some kind of fat.

A correct appreciation of the benefit of fat food in the Arctic regions serves as an index to its advantages under other conditions. It is not limited to blubber, 'toodnoo' or oil, even among the Laplanders. It includes the solid portions of reindeer, seal and other meat. And this in its composition doubtless compares favorably with the choicest cuts of beef and mutton, which consist of 20 to 30 per cent. of fat; or possibly with good bacon or ham, 35 to 50 per cent. Good butter, it need hardly be said, is almost wholly fat—85 to 90 per cent.

Of approximate stamina and exemption from tuberculosis, it is not far fetched to refer to the history of most of the North American Indians, before the cultivation of cereals was introduced by the white settlers. Their food was almost exclusively the fat game which they hunted and killed in such a manner as to retain the blood. Of the wonderful physical strength and endurance of those savages, their history of them furnishes many examples. And the earliest records of consumption among them are contemporary with the attempted methods of civilizing them—inducing them to leave their tents and live in houses; restricting their game supply and supplying them with an excess of farinaceous food. They have ceased to be a hardy race and tuberculosis is common among them. The Gauchos of the South American pampas, who live almost exclusively upon fat animal food, are alike remarkable for their extraordinary stamina. The flesh-eating Mahometans of India are described by historians as being the most powerful, active-minded and hardy race of human beings in the world, presenting the widest possible contrast in physical development to the rice-eating and feeble Hindoos, of whom but few reach the age of forty years.

A striking example of what appears to be the result of a change from an almost exclusive fat meat diet to one largely farinaceous, in relation with tuberculosis, is afforded by the history of the New Zealanders, who, until about fifty years ago, were cannibals, eating their captives in war, but who besides consumed an enormous amount of fat pork. Dogs also composed a part of their dietary, and fish to some extent. They were remarkable for their physical development and exemption from tubercular diseases. But soon after the introduction of the potato as a staple food, at about the time mentioned,

scrofula and other forms of tuberculosis began to prevail among them, and have attained a degree of prevalence even greater than among the poorest people in Ireland, where the staple food is of the same kind, but beneficially supplemented to a considerable extent by the use of buttermilk.

Moreover, I have observed among people in the tropics, as well as in temperate latitudes, that there is a marked difference in the health of persons whose chief food is farinaceous, between those who but rarely eat anything else and are particularly feeble, lymphatic and scrofulous, and those who eat butter or oil with their rice and similar food, or supplement it with sardines in oil, or oil-dressed salads.

Recurring to what I have remarked on the superiority of meat that retain the blood as well as the fat, every epicure knows, and every physician ought to know, that the meat of animals of every kind so killed as to retain the blood is more delicious than that of animals otherwise killed. It is also more digestible and more nutritious. All fresh meat is more or less acid, and that from which the blood has been drained requires to be kept until alkalinity is induced by incipient decomposition before it becomes tender and digestible. On the contrary, that which retains the blood only requires thorough cooling before it is ready for cooking and is tender and digestible from the outset, because the alkalinity of the blood speedily acts upon and neutralizes the acid. Hence, the meat of the buffalo, as it used to be killed and prepared by the North American Indians; the jerked beef of the Gauchos; the beef of cattle that have been knocked in the head, or preferably, by dividing the spinal marrow in the neck, as now practised in the abattoirs of Chicago (if it is not afterward drained of its blood), is greatly superior to that which is prepared after the method of the Jews. Besides, the draining or soaking away of the blood from meat impairs its nutritive value. The blood is essentially of the same composition as the flesh, but besides, it holds in solution phosphates of soda, salts of potash, iron and sulphates; all nutritives of vital importance to the human economy. But there is no method of slaughtering animals that entirely divests the flesh of blood, hence to attempt to prohibit eating it, to be effective, should prohibit the eating of meat altogether.

Relative exemption from tuberculosis, under all circumstances, is, according to my observation, due to the generous use and potentiality of fat food. My conclusion in this regard is fortified by many years' observation and study of the liability to consumption of people collectively, families and individuals, more or less proportional to their abstinence from fat foods. The most prominent example, of which I have never lost sight from youth up, is the negro race in America. I began my professional life among them when they were slaves and

were always supplied with an abundance of 'hog and hominy,' not by any means restricted to these articles, but pork or bacon was a standing portion of at least one daily meal. Consumption among them was relatively rare. My observation in this respect was not singular, but accords with all other medical observers of the time, of whom I have knowledge. Conversely, it seems hardly necessary to invite attention to the prevalence of consumption among the same people now, under their changed conditions with regard to diet. 'Hog' at least is notable by its absence from the daily fare of most of them and no other fat meat has taken its place; and consumption among them is more than twice as great as it was formerly.

The same observation extends to smaller communities, families and individuals. Consumption is most prevalent among those who are stinted or who stint themselves of 'bacon' and 'butter.' I mention these as ideal and because they are among the most digestible of fat foods; other fat foods are commendable. Everybody has learned, when it is unfortunately, in most cases, too late, that cod-liver oil is good for consumptives, but few seem to have learned that food of the same character as cod-liver oil, suitable for the table, is preventive of consumption.

In the whole course of my professional observation, now covering a period of more than sixty years, I have never known a family or an individual that was brought up on a liberal supply of butter and bacon who became tuberculous. Moreover, such food fortifies the system against other diseases as well as consumption; it establishes stamina.

THE NATURAL HISTORY OF ADOLESCENCE.*

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THE history of philosophical thought itself participates in the scheme of evolutionary progress which it expounds and records. The sequence of culture changes and the soil of motives in which these find root remain the permanently vital sources by which to illustrate and to comprehend the nature of human endowment, striving and achievement. For only half a century have we had access to an adequate point of view that brings into the vista of the progress of the ages the nature and the scope of evolutionary forces. This added insight has come, more than any single factor, to stamp the pattern of modern thought. We look backward not only with a different equipment in the way of telescopic aids to such retrospective vision, but with very different anticipation of what is thus to be discovered, and of its significance.

Though the application of evolutionary principles to mental endowment has kept pace with its advance within the more strictly biological field; and though the factors which psychological processes have themselves contributed to the trend of evolution have been of late prominently recognized, yet the sum-total of these recognitions has gone rather toward adding some chapters and an appendix or two to the volume of philosophy, than towards the rewriting of the whole. Yet the latter type of reconstruction of philosophy and psychology is by no means unrepresented. The manner of such representation naturally varies with author and subject, with scope and purpose; but it is possible to set down a score or more of titles indicative of the absorption into the ripest psychological thought of the tissue of evolutionary doctrine. In some aspects this tendency appears in a still more intensive and comprehensive form than has yet been accorded it, in the psychological work of large dimensions which President G. Stanley Hall has recently brought to an issue. The dominant message of his pages is the notable one that psychology must ever remain close to biology; that considerations of origin and of the potent past must ever illuminate the road to the future.

* 'Adolescence, its Psychology and its Relations to Physiology, Anthropology, Sociology, Sex, Crime Religion and Education,' by G. Stanley Hall, Ph.D., LL.D., president of Clark University and professor of psychology and pedagogy. D. Appleton and Company, New York, 1905. Two volumes. Pp. 589 + 784.

The central topic about which this doctrine is elaborated is that of adolescence—that specialized, reconstructive period fraught with the highest possibilities and the severest risks for the future of the individual, and representing nature's point of emphasis in the perspective of human and racial development. The volumes accordingly constitute in the first place an encyclopedia of adolescence. They bring together with a degree of completeness quite unattempted hitherto, the main data concerning the natural history of this period of unfoldment, on its physical, physiological and psychological sides. The normal growth of the body, the special development of different portions thereof concerned with adolescence, the variations from such normal development and their aberrations in disease and crime, the great rôle that periodicity plays in human growth—these constitute the physical basis which conditions through and through the nature of mental growth, as well as determines the spirit of educational progressions. The considerable aggregate of special studies that have been made in all parts of this wide field are here carefully summarized; so that as a book of reference the work takes a commanding position. There will be a variety of opinion as to the specific and permanent value of much of this evidence; and there may be some who will call into question the validity of the question-sheet system by which much of the psychological portion of the material has been gathered. Yet those who weigh evidence in a fair spirit of criticism will find that on the whole the weakness of certain types of evidence, for which unfortunately we have no better substitute, is quite as clearly recognized by the author as by themselves. It is easy enough to discredit the results obtained by a somewhat miscellaneous set of answers to questions, many of them rather difficult to answer with conscience and pertinence. But here, as everywhere in statistical investigation, all depends upon the temper and discretion that are used in the interpretation of the results. If the method used for the extraction of the result is adapted to the nature of the material, then it is likely that the investigation, however deficient, has served a useful purpose. It is not necessary to defend the *questionnaire* system in itself or the use which Dr. Hall and his pupils have made of it; the real point of issue is how far such material will stand the strain of the conclusions which are based thereupon. Allowing for a wide divergence of opinion in this respect, there remains a very considerable body of evidence which is tangible and well classified, and in the aggregate has a significance in that it suggests the trend of emphasis of the growth and distribution of mental traits. It is difficult, indeed, to understand by what other means an equally adequate conception of the contents, the impulses and the modes of feeling of young minds could have been ascertained, or the larger conclusions involved therein more saliently suggested. Nor must it be supposed that Dr. Hall has limited himself to this form of evidence.

Quite apart from the more physical investigations, where statistical methods yield more concrete and definite results, he has utilized direct experimentation where that has been possible, has cited the larger records of history, of literature, and of the more technical portions of psychology and biology. It must forever remain true that advance in this field of comparative psychology must make use of arguments by analogy, of parallelisms, assisted by direct reinforcement of evidence from the investigations of animal life, from the study of the abnormal, from the lessons of history. Method here is not a matter of theoretical preference, but of judgment; and the ability that can turn method into account, not subordinating the chief end to its requirements nor distorting method to strengthen favorite conclusions, is the equipment which the investigator in this field must possess to an unusual degree. Appreciating the difficulties of this undertaking, students of psychology and education, unless they believe that Dr. Hall is fundamentally following a false clue, have reason to be deeply grateful for so much of this work as constitutes an encyclopedia of adolescence. They have the privilege, which many will doubtless exercise, of discrediting this or that group of data; but they can hardly help recognizing that the general perspective of importance and bearing based upon the material thus made available, has on the whole been ably reproduced.

The chapters that best represent this encyclopedic feature are those that deal (the first two) with the varied and detailed factors of physical changes of growth; the fourth, which deals with the disorders of immaturity; the ninth, that treats of changes in the sense endowment and in the voice; and again the later chapters, recounting from a more historical point of view the recognition of adolescence in custom (Chapter XIII.), in religion (Chapter XIV.), in society (Chapter XV.), together with the racial problem of adolescence, which must be treated both theoretically and practically whenever higher races come in contact with lower ones (Chapter XVIII.). A second group of chapters takes up more specifically those questions that are central to adolescence, and in which the element of sex predominates. Chapters VI. and VII. consider the more physiological portions of this problem; Chapter XI. is devoted to adolescent love; while Chapter XVII. contains a *résumé* of the entire topic of the feminine side of adolescence in psychology and education. A third group of chapters includes those in which the philosophic basis is uppermost and which together constitutes in some measure a statement of the author's philosophical and psychological point of view. Chapter X., on evolution and the feelings and instincts characteristic of normal adolescence; Chapter XVI.; on intellectual development and education; Chapter VIII., which considers adolescence in literature, biography and history, represent the more distinctively philosophical contributions; while Chapter III., on the development of the motor powers, represents the

best illustration of the combination of all three interests as applied to a single topic.

The selection of this third group of topics for more especial notice is the natural one, as therein are contained the points of view that have directed the entire work as it became formulated in the author's mind, and upon the value of which its ultimate standing will depend. What is known as the 'recapitulation theory' becomes in Dr. Hall's treatment a direct aid to interpretation as well as a guide to interest and application. Its central message is fairly familiar, and emphasizes the fact that there is contained in our physical and functional heredity the vestiges of the several slow and tortuous changes that have intervened between the earliest forms of life and their successive unfoldment into that diversified series of organisms culminating in *homo sapiens*. The doctrine thus means that the oldest of human structural traits and functional tendencies must find their analogy, as well as their type of explanation, in a study of animal and of primitive human characteristics.

Like many a biological trait, and most typically like the great fact of sex itself, this principle has a wide range of secondary implications. Among these the accounting for present human traits, by means of those strongest in primitive life, of the type that we find among uncultured peoples, is of all the most comprehensive. It gives to that longer and more fundamental life of human endeavor a living participation in the make-up of present psychic traits, and prevents an overestimation of the importance of those newer and less inwardly absorbed tendencies which we too exclusively regard as coming within the ken of psychology, and too exclusively train in systems of education. More concretely, this principle emphasizes the importance, for the comprehension and the training of minds, of the life of the feelings and of the will. Men have felt and men have acted for ages before they guided their actions by thought; and the reverberation of these long emotionally ruled periods must have left decided traces upon those tendencies which will best be expressed in the early and adolescent stages of the individual. The history of philosophic opinion itself in interpreted by Dr. Hall in terms of a similar development, in which immature adolescent systems, staid senescent and *blasé* philosophies have appeared and appealed to their public in direct relation to the status of the culture-periods in which they found origin and favor. Our own day is decidedly that of the exaggeration of the rational processes, of complete subordination of feelings and will to thought. This type of cerebration is as evident in the studies that we teach, in the education that we favor, as in the philosophies that we read. With the last, indeed, Dr. Hall has a special issue; regarding, as he does, that this indulgence in speculation of the theory-of-knowledge type, has tended to inject unduly into psychological considerations the spirit and the

interest of metaphysicians. The explanation in philosophical terms of thought and reality has usurped, in his opinion, the larger, more fruitful as well as more hopeful interest in the functional manifestations of the deeper, more universal and significant aspects of mind.

An analagous emphasis must be placed upon action as opposed to thought. The study of motor impulses becomes as fundamental in psychology, and motor training as fundamental in education, as any analysis of how we think, or any teachable wisdom in the guidance of thought. The motor response is as vital to the psychological mode of manifestation as the ability to defend policy by argument or to analyze results into processes. In all these several aspects the position of woman has remained closer and truer to nature than that of man. And to this, the specific trait of feminine psychology, Dr. Hall traces her peculiar distribution and emphasis of brain, heart and hand—a distribution that represents an older, more typical as well as more natural set of relations. The educational application of these several principles lies close at hand. Indeed, to some readers the volumes, as a whole, will appeal more strongly on their practical side as a guide to education than on their analytic side as a guide to a perspective of importance of the several contributory factors of modern psychology. These educational applications are stated with considerable elaboration, at times with distinct and exaggerated oratorical appeal, and as frequently with suggestive and earnest reformatory programs. No one of these practise-guiding principles is more convincingly dealt with than that which leads to the appeal for the proper representation in the educational scheme, of the training of the hand and the will. The dignity and rights of motor education receive an unusually strong and comprehensive recognition. And here as elsewhere, we are reminded in general and in detail that the order of control over muscles and the apparatus of the will is indicated by its natural growth in the child and in the race. The value of the discovery of the natural order in this as in other series of evolutions is that the natural order is the right order; that our efforts should go to encourage for the several periods the conditions and stimuli that nature provides, to avoid at least the most serious of the antagonisms to that sequence of growth, which the needs of civilization (or our imperfect means of preparing for them) seem to demand.

The crowning application of these several precepts and practices is to those special phases of growth which find their joint issue in adolescence. Here more than anywhere else must the natural sequence of evolution determine the variety of occupation that shall prepare for the adult life; and here too, according to Dr. Hall, have our transgressions against the order of nature been most serious. We have imposed upon the adolescent endowment the interests of mature individuals, have invited them to share our adult consciousness, not even taking care

to adapt the methods of assimilation to the apperceptive appetite of the young. And the extreme instance of such misapplication is in the efforts of those who attempt to assimilate the education of women to that of men, and who take as their model the type of masculine education against which these strictures most especially apply. Not that the author is arguing against the higher education of women or even specifically against all forms of coeducation, but that he makes a plea both for young men and for young women, for that form of education, and for such favorable conditions of growth, as correspond in both cases most nearly to their individual and very different needs. Thus psychology—properly interpreted as the study of the evolution of mental functions—at once appraises the value of mental traits, and in recovering the trade-routes of the past, points to the most profitable highways of the future. Psychology of this type and temper remains the supreme guide of education. The discussion as to what benefit this or that teacher, or teachers as a whole, may derive from the study of psychology is not prominently considered; yet the affirmative attitude towards the problem is implied. But particularly are we asked to discountenance as of slight profit, or even as pernicious, that type of psychologizing that remains unrelated to the vital functions of life, 'If truth is edification, the highest criterion of pure science is its educative value.'

With this estimate of the nature and purpose of psychological inquiry, Dr. Hall attacks with an almost bewildering variety of equipment the entrenched position of adolescence. This is central, the key to the situation, because the maturing of mind and body which then takes place represents the key-stone of the arch which up to then has been building. It indicates that the stages of mental growth anticipating adolescence form a separate and formative type of psychological study; that a knowledge of the changes which then take place is as vital a matter of human concern as can well be imagined; and that the shaping of interest, which then first buds, remains the supreme question of educational practice. Thus both for education and for psychology, adolescence has a directive importance. The weakness, alike of education and of psychology is, in Dr. Hall's opinion, largely due to the comparative neglect of those interests that the study of adolescence discovers and illuminates. Education and psychology are in danger of becoming scholastic because they are fashioned too much in the study and by the book, and reflect too little knowledge of the world and of the byways as well as of the highways of life. It is, after all, but a small part of psychology that can profitably concern itself with how the mental processes of the adult consciousness can best be presented and explained. A far more vital and comprehensive problem is the comprehension of how men and women, and particularly boys and girls, feel and act as well as think. The study of impulse and motives, not merely of such as lie in a direct line or cultural advance, but equally

those that suggest the abnormal, that which when magnified becomes disease, and most of all that which harks back and suggests the psychic mode of action of our primitive ancestors, merit chief consideration; such, apart from the specific applications to the physical and mental hygiene of adolescence, are the conclusions and argument that have guided the author in years of labor, compilation and record.

The effect of so comprehensive and many sided a work as this inevitably depends in no small measure upon the manner of its presentation. This is uneven in the several chapters and rises to the point of complete satisfaction in few. To many the style will be distinctly unattractive, as it suggests a somewhat Teutonic attempt to carry more luggage than the journey warrants. Some will find it a loss to their special purposes to have the special presentation of facts so closely interwoven with the enunciation of principles. More will object to the cumbersome sentences, elaborated paragraphs and detailed summaries. It must be confessed that these frequently suggest the mode of progress of the burdened stage-coach rather than the directness of the pony-express. But as some traverse the ground with the interest of prospective settlers, and others with that of tourists only, it would be difficult in any event to satisfy both needs. Yet in this respect the work falls short of that pedagogical effectiveness upon which the author himself lays emphasis. Indeed, he must not be surprised to find the charge which he makes against other systems of philosophy, namely, that they open large vistas, but that the view enjoyed therefrom is distant and hazy, will be applied against himself. Yet one must hasten to record that the practical issues are nowhere lost sight of, though the path followed in bringing them to light is often needlessly detailed and circuitous.

That equal exception will be taken alike to the main positions of the work and to the detailed applications therein is not unexpected. Dr. Hall distinctly appreciates the imperfection of his own efforts; but these efforts represent the convictions of as long a stretch of teaching and of as close study of a wide range of data, as is the case with any representative of his craft. In a more distinctive way than any other student of mind in America, Dr. Hall has canvassed the field both on its practical and theoretical sides, and has bided his time for many years, eventually placing on record this issue of his encyclopedic labor, his varied experience, his wide observation of men and things. Quite irrespective of the degree to which his views will find ready acceptance among his colleagues and the public at large, the importance of the problems discussed and the originality contributed to their discussions, as well as the encyclopedic comprehension of what is thus put together, make these volumes a distinctly notable achievement in the field of psychology and education.

The objective account thus rendered of the comprehensive under-

taking serves the purpose of indicating its contents, its arguments and the trend of its conclusions. Such an account is inevitably incomplete, but suffers a conspicuous incompleteness if it refrains wholly from any expressly critical estimate of the value and probable influence of the more original and distinctive doctrines for which the work stands. In regard to methods and the kind of criticism which they invite and will doubtless receive, enough has been said. The most pertinent inquiry pertains to the attitude which close students of psychology and of education are likely to assume towards the main positions of the author, and—equally important—the impression which the views thus first formally recorded are likely to make upon the considerable circle of interested and intelligent laymen. In this connection it is not of paramount importance that one should speak exactly for himself, legitimate as that would be; it is equally pertinent to set forth as well as may in him lie, the attitude of those who share with him many of his interests and his general perspective. Approaching the matter with this purpose, one notices a larger representation on the opposition benches than in those set aside for the government supporters. The case of the opposition will be strong and carry a fair measure of conviction; the argument will be advanced, that while the principles thus advanced carry some measure of support from biology, the use to which said principles are put far transcends the warrant of the evidence, and in certain of the deductions seems indeed in contradiction to it. The biological status of recapitulation leaves no such definite provision, not even in the earliest stages of infancy, for such complex appearance of prehuman traits as Dr. Hall advances. To explain the impulse of children when in the presence of water to jump in and swim, as a reverberation of an aquatic habit, seems both feeble and inconclusive. The case becomes stronger and at the same time changes its aspect, when traits favored by primitive human life are brought into operation to account for the vast medley of impulses and feelings which in great part we have shared and then outgrown. Yet even here the transfer from the one field to the other seems better justified when limited to general groups of traits than when literally translated into the deciphering of the variable and complex as well as evanescent characters of changing juvenility. In other words, many who will admit a limited applicability of the general parallelism would hesitate to stand sponsor for the special application and practical deductions that seem the goal of so many of the Clark University studies in this field. Nor is it going too far to add that Dr. Hall's educational insight has a firmer hold upon his pen than his logical adherence to the recapitulation theory. His educational precepts impress one as finding their inspiration in a broad and discerning observation, intermittently reinforced by an elaborated conformity to the principle which at times becomes only imperfectly germane to the plan and the spirit of the

exposition. In brief, psychologists are rather likely, with a reasonable variation of cordiality, to endorse the emphasis which Dr. Hall's studies have led him to place upon certain aspects of mental evolution, but rather unlikely to endorse his special and insistent applications thereof. Likewise will they hesitate to join forces with him in his subservience of so many other normative trends in psychology to the dominance of the evolutionary and atavistic influences from which in his accounts so many human blessings and their opposites flow.

It has already been indicated that psychologists and laymen alike will find their sense of obligation to those volumes lessened by certain peculiarities of presentation that seem to result from a too ardent desire for judiciously modified and at the same time richly comprehensive statements. This detraction from the possible influence of the work is more serious for the layman; and it is to be feared that these volumes, extensive and difficult to read, will lose a considerable measure of the influence which the interest of the subject would have, under more favorable circumstances, commanded. Equally must it be said that the extreme, and to many minds needlessly urgent, frankness in the treatment of topics usually (even if we admit at times unwisely) debarred from public consideration, will give offense in quarters where a less drastic treatment would have saved the situation without sacrificing the pedagogical effect. That this element in the work has already led to the exclusion of the volume from certain public libraries can easily be ascertained. Those who read between the lines will acquire a conviction of greater sympathy with the author than with his book. They may come to feel, what those who are acquainted with the author's career know, that his influence in shaping psychological and educational interests is sounder and more effective and distinctly more suggestive than his recorded position. These mixed feelings of attraction and repulsion, together with the strain of orientation of thought already referred to, will further diminish the influence of the volumes among the lay public. This criticism may be fairly interpreted to mean that the author has attempted too complex and many-sided a task, rather than that he has in any sense failed to accomplish the purpose which he set before him. It may well be that two different books, each addressed to a separate set of readers, would have diminished the sense of lack of fitness to their special needs which the layman and the psychologist—to say nothing of the student of education—now feel.

Having thus indicated the characteristics of the volumes which are likely to detract from the more general acceptance of the positions taken therein and from a proper appreciation of the work among lay readers, it remains only to repeat the estimate more objectively stated above, that the comprehensiveness of the task and the ability of the author will in the end, and in more directions than have here been indicated, gain for the work a distinct recognition as one of the notable contributions of American scholarship to the field of psychology.

HIGHER EDUCATION OF WOMEN AND RACE SUICIDE.

By A. LAPTHORN SMITH, B.A., M.D.

MONTREAL.

EDUCATION on the continent of America, and more especially in the United States, has reached a point of perfection which hardly leaves room for any further development.* At first sight, this would seem to be a very satisfactory state of affairs and, to the ordinary observer, the question of still higher education would seem to be deserving of all praise. 'You can not have too much of a good thing,' they say, and the very highest possible degree of education for women is none too good or too great for them. But to those who look beyond the present and only a little way into the future a great danger is gradually arising, a danger which will go on increasing until it brings about a revolution the signs of which are already beginning to be seen and which will effectually put an end to the evil which is to form the subject of this paper. The author will limit himself principally to a discussion of the harm resulting from too high an education of women, because on that part of the subject he has had exceptional opportunities for observation and for drawing accurate conclusions; but, incidentally, he will take the liberty of questioning the advisability of affording *higher* education freely to the people at large, of the male, as well as of the female sex.

The author regrets to be like a voice crying in the wilderness, a note of warning against what the majority of people consider to be an unalloyed blessing; and some will no doubt say that he is going back to the time of the great preacher who said 'he that increaseth knowledge increaseth sorrow.' And yet all the facts on which his conclusions are based are known to many thousands, and even millions, of people in America, and even, though to a lesser extent, in England, where the same disastrous results are following the same apparently innocent cause. The author would crave the indulgence of his readers, if, at times, he is obliged to speak of delicate matters in rather a plain way; but where this has to be done he will endeavor to do it in such a manner as not to offend the sensibilities of any scientific reader.

In the human race, as among every species throughout creation, as every well-informed person knows, there is constantly going on

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* The American boy is generally admitted to be the *smartest* on earth, while the American girl is still more clever and brilliant than her brother.

a struggle for existence—not only for the existence of the particular individual, but for that of his progeny, which is of far greater importance in nature, because when the individual is wiped out, only one person disappears; but when his progeny ceases to exist, an end is put to countless thousands, who are thus prevented from ever being born. He will endeavor to show, as he believes to be the case, that the higher education of women is surely extinguishing her race, both directly by its effects on her organization, and, indirectly, by rendering early marriage impossible for the average man.

First of all, is education being carried on at present to such a degree as to at all affect the bodily or physical health of women? This is a very important question, because the duties of wifehood, and still more of motherhood, do not require an extraordinary development of the brain, but they must absolutely have a strong development of the body. Not only does wifehood and motherhood not require an extraordinary development of the brain, but the latter is a decided barrier against the proper performance of these duties. Any family physician could give innumerable cases out of his experience of failures of marriage, directly due to too great a cultivation of the female intellect, which results in the scorning to perform those duties which are cheerfully performed, and even desired, by the uneducated wife. The duties of motherhood are direct rivals of brain work, for they both require for their performance an exclusive and plentiful supply of phosphates. These are obtained from the food in greater or less quantity, but rarely, if ever, in sufficient quantity to supply an active and highly educated intellect, and, at the same time, the wants of the growing child. The latter before birth must extract from its mother's blood all the chemical salts necessary for the formation of its bony skeleton and for other tissues; and in this rivalry between the offspring and the intellect how often has not the family physician seen the brain lose in the struggle. The mother's reason totters and falls, in some cases to such an extent as to require her removal to an insane asylum; while in others, she only regains her reason after the prolonged administration of phosphates, to make up for the loss entailed by the growth of the child. Sometimes, however, it is the child which suffers, and it is born defectively nourished or rickety, and, owing to the poor quality of the mother's milk, it obtains a precarious existence from artificial foods, which at the best are a poor substitute for nature's nourishment. The highly educated woman seems to know that she will make a poor mother, for she marries rarely and late and, when she does, the number of children is very small. The argument is sometimes used that it is better to have only one child and bring it up with extraordinary care than to have six or eight children brought up with ordinary care because in

the latter case the mother's attention is divided. But this is a fallacy. Everybody knows that the one child of the wealthy and highly educated couple is generally a spoiled child and has as a rule, poor health; while the six or eight children of the poor and moderately educated woman are exceedingly strong and lusty. But even supposing that the highly educated woman were able and willing to bear and rear her children like any other woman, she has one drawback from having a fairly large family, and that is the lateness at which she marries, the average being between twenty-six and twenty-seven years. Now, as a woman of that age should marry a man between ten and fifteen years older than herself, for a woman of twenty-seven is as old as a man of forty for the purpose of marriage, both she and her husband are too old to begin the raising of an ordinary sized family. Men and women of that age are old maids and old bachelors. They have been living their own lives during their best years; they have become set in their ways, they must have their own pleasures; in a word, they have become selfish. And, after having had one or at the most two children, the woman objects to having any more, and this is the beginning of the end of marital happiness. The records of our divorce courts show in hundreds of instances, that there was no trouble in the home while the woman was performing her functions of motherhood, but that trouble began as soon as she began to shirk them. Hundreds of thousands of men at the present day are married, but have no wives; and while this sad state of affairs occurs occasionally among the moderately educated, it exists very frequently among the highly educated.

Is the health of the women at the present day worse than it was in the time of our grandmothers? Are the duties of wifehood and motherhood really harder to perform now than they were one hundred years ago? Without hesitation the answer to both questions is 'Yes.' Not only are the sexual and maternal instincts of the average woman becoming less and less from year to year; the best proof of which is later and later marriages and fewer and fewer children; but, in the writer's opinion, the majority of women of the middle and upper classes are sick and suffering before marriage and are physically disabled from performing physiological functions in a natural manner. At a recent meeting of a well-known society of specialists for obstetrics and diseases of women, one of the fellows with the largest practise in the largest city on this continent stated that it was physically impossible for the majority of his patients to have a natural labor, because their power to feel pain was so great, while their muscular power was so little. On these two questions the whole profession is agreed, but I am bound to say that there is a difference of opinion as to the reason. Several of the most distinguished fellows of the above society claim that the generally prevalent breakdown of women is due to their inor-

dinate pursuit of pleasure during the ten years which elapse between their leaving school and their marriage. This includes late hours, turning night into day, insufficient sleep, improper diet, improper clothing and want of exercise. The writer claims that most of the generally admitted poor health of women is due to over education, which first deprives them of sunlight and fresh air for the greater part of their time; second, takes every drop of blood away to the brain from the growing organs of generation; third, develops their nervous system at the expense of all their other systems, muscular, digestive, generative, etc.; fourth, leads them to live an abnormal single life until the age of twenty-six or twenty-seven instead of being married at eighteen, which is the latest that nature meant them to remain single; fifth, raises their requirements so high that they can not marry a young man in good health.

There is another aspect of the question, which is not often discussed, but which has an important bearing upon it. The very essence of cultivation of intellect to its highest point consists in raising the standard of one's requirements. A contented mind makes a man happy. Does a high education make one's mind contented, or does it make it discontented with the present, and ever struggle towards a higher ideal in the future? Is the woman who is versed in art and literature contented with a simple home, or must she be surrounded with objects of art and more or less costly books; and, if so, is she satisfied with her lot when she marries an average man, who is able to provide for her all the necessaries of life, but is not possessed of sufficient wealth to provide those things which would be useless luxuries to a woman of ordinary education, but which are necessities for her? Not only must the highly educated woman have an artistic home, large enough to hold her artistic and literary collections, and roomy enough in which to entertain her artistic friends, but she must have a certain number of expensive and highly trained assistants, to keep these large collections in proper order. In plain language, she must have servants to clean them and move them about without destroying them. Can such a woman, anxious and worried over the care of several thousands or hundreds of objects of art, devote the same care to the bearing and bringing up of her family as the woman whose ordinary education has made her feel no need of possessing such objects, but who, on the contrary, is content with a home and furniture which she herself is oftentimes alone capable of taking care of?

We all want to be happy, and to that end we all want to be good; and, I have already said, we want our children, especially our boys, to be good and happy. But those who know anything about virtue in the male know that the marriage of our young men under twenty-

five, to a woman with a sound body about eighteen years of age, is almost, if not the only, means of preserving the virtue of the rising generation of men. People, and even mothers, speak lightly of their daughters at twenty-six or twenty-seven marrying men who have sown their wild oats; but one must reap what he sows and do they realize what an awful misfortune such a harvest has brought to the character of the man, and will almost surely bring to the health of the innocent woman? If one has any doubts on this subject they would soon be set right by the testimony of any physician who has made a specialty of attending men, or who has devoted his practise especially to women.

Just as there are occasionally cases where a divorce becomes necessary, but very much fewer than those actually granted, so, occasionally, the life of an unborn child must be sacrificed to save the life of the mother. But will anybody pretend for a moment that there is any excuse for the two million of child-murders which is a fair estimate of the number occurring annually on the North American continent? The crime has become so general that public opinion has ceased to condemn it, and among the few who do condemn it we certainly do not find those women who claim that wifehood and motherhood are degrading and should be reserved to the lowest class of the population. It is well known that were it not for the enormous immigration pouring into America day by day and week by week, the population of this continent would have died out ere now. And it is generally admitted that the original American people have almost died out. Even the foreigners who are so quickly assimilated soon learn the practise of race-suicide, although never to the appalling extent of the native-born Americans. As far as my experience goes, the crime is most prevalent among the highly educated classes, while it is almost unknown among those with an ordinary education.

Another way in which the higher education is making people unhappy is in the cultivation of the powers of analysis and criticism. When the power of analysis is applied to one's own self it is especially unfortunate, for then it becomes introspection, a faculty which is carried so far with some women that their whole life is spent in looking into themselves, caring nothing for the trials or troubles of those about them. This produces an intense form of egotism and selfishness. These people are exceedingly unhappy, very often suffering from what is wrongly called 'nervous prostration,' but which should rather be called 'nervous prosperity.' When the wonderful power of criticizing is applied to others it takes the form of fault-finding. Such a woman must have many victims; will she make them happy?

One of the greatest objections to the higher education of women, namely, the interference with outdoor exercise, no longer can be raised,

because the universities and boarding-schools have within the last ten years foreseen this danger and met it by special courses of instruction in athletics and the encouraging of girls to spend a good deal of time in outdoor sports. But even these universities and schools cannot avoid the charge of fostering a condition of intellectual pride, which is in exact proportion to the success of the school or college. There is no doubt that women can do everything that men can do, and a great deal more; but the knowledge of their ability brings with it an aggressive, self-assertive, independent character, which renders it impossible to love, honor and obey the men of their social circles who are the brothers of their schoolmates, and who in the effort to become rich enough to afford the luxury of a highly educated wife have to begin young at business or in the factory, and for whom it is impossible to ever place themselves on an intellectual equality with the women whom they should marry. These men are, as a rule, refused by the brilliant college graduate, and are either shipwrecked for life and for eternity by remaining single, or are only saved by marrying a woman who is their social inferior, but who, by reason of her contented mind, in the end makes them a much better helpmate than the fault-finding intellectual woman who is looking for an impossible ideal.

The catholic church has, for many centuries, realized the importance of marriage and maternity in the upbuilding and strengthening of religious life in the community; and if the protestant churches are not to be emptied of their male attendance, the protestant clergy must speak out in no uncertain tone against the present methods of education, which are turning out women by the thousands, with requirements so varied and so great that no young man can afford to marry them; a step, moreover, which he is deterred from taking by the discouraging report of those of his friends who have ventured to marry the women of their own class, and who have advised them, in the words of Punch: 'To those about to marry, don't.' Whether a man should marry or not is too often spoken of lightly and as a joke. But to those who believe in the immortality of the soul, and that the whole world avails nothing to a man if he loses it, the possibility of early and happy marriages becomes a question of the vastest importance and one which students of sociology, and the fathers of the nation should study with the most intense anxiety and care.

Occasionally a college graduate goes through the ordeal* of a high education, which has developed her intellect without ruining either

* The following subjects from the curriculum of a well known girl's college: Latin, Greek, French, German, English, mathematics, physics, chemistry, astronomy, history, sociology, economics, logic, psychology, philosophy, literature, fine arts, biology, physical training, physiology.

her body or her natural instincts; but, as far as the writer can see, she is decidedly an exception. To the average highly intellectual woman the ordinary cares of wifehood and motherhood are exceedingly irksome and distasteful, and the majority of such women unhesitatingly say that they will not marry, unless they can get a man who can afford to keep them in luxury and supply them with their intellectual requirements. The gradual disappearance of the home, which any thoughtful observer must deplore, is, to a large extent, the result of the discontentment of the educated woman with the duties and surroundings of wifehood and motherhood, and the thirst for concerts, theaters, pictures and parties, which keep her in the public gaze, to the loss of her health and the ruin, very often, of her husband's happiness.

Fortunately, nature kills off the woman who shirks motherhood, but, unfortunately, it takes her a generation to do it; and in that short lifetime she is able to make one or many people unhappy.

What about the supply of female school teachers? Is not the very highest education possible necessary for them? From the writer's point of view most of the women who are now teaching school should have been married at eighteen and in a house of their own which might have been the schoolmaster's home. The profession of teaching was once exclusively in the hands of the men, and it can not be denied that they have achieved some great results. But as education rendered an ever-increasing number of women unsuited for marriage, that is, unwilling to marry the available men, they invaded the schoolmaster's rank to such an extent that his salary has been cut down one half, and now he is unable to marry at all. Two well-known consequences have followed this state of affairs; first it is impossible to get men in sufficient numbers to become teachers for the boys' schools; and secondly, even big boys being taught by women, the effeminization of our men is gradually taking place. Although there are some instances of a mother alone having formed her son into a manly man, yet as a rule the boys require the example of a man's character to make them manly men. This subject has recently been dealt with in several elaborate papers by well-known educationalists, to whom it appears to be a real danger to the coming generation.

What about the men? If the higher education prevents the women from being good wives and mothers, will it not prevent the men from being good husbands and fathers? To some extent it does, and in so far it is a misfortune, but to a much less extent than among women, for the simple reason that the man contributes so little towards the new being; while, on the other hand, high intellectual training enables him to win in the struggle for existence much better than if he were possessed of mere brute force. But nature punishes the man

who has all the natural instinct cultivated out of him, just as it does the woman, namely, by the extinction of his race. For the struggle for existence among the highly educated men has become so keen, because there are so many of them, that great numbers of them are unable to earn a living even for themselves; while the supporting of a highly educated woman, with her thousand and one requirements, is simply out of the question. A president of a great company recently informed the writer that he had, in one month, applications from eighty-seven university graduates for a position equivalent to that of an office boy at fifteen dollars a month while out of one hundred millionaires, at least ninety-five of them are known not to have been highly educated; but, on the contrary, to have left school between fourteen and sixteen years of age. So there is such a thing as learning too much, without knowing how to do anything. Just as athletes may be overtrained, so men may be overeducated.

This great question has received the attention of one of the brightest men of our age—no less than the chief magistrate of the United States; while quite recently, in the British House of Lords, the Right Reverend Dr. Boyd-Carpenter, Bishop of Ripon, from his seat in that august assemblage, has called attention to the lateness of the age for marriage and the diminishing birth-rate, foreseeing, no doubt, that these two factors would soon be followed by the emptying of the churches and the lowering of the high standard of British morals and character.

The writer feels certain that, before long, this subject will receive the attention which it deserves from those who love their country and have the forming of its destiny in their hands. If he succeeds, by this or any other means, in drawing their attention to it, he will have fulfilled the object of his paper.

SIMPLE BACTERIOLOGY FOR PUBLIC SCHOOLS.

By LILLIAN CHAPIN, B. S.,

INSTRUCTOR IN CALUMET HIGH SCHOOL, CHICAGO.

HYGIENE is the one secondary school subject that every pupil will find necessary throughout life. In few high schools, however, has it received the treatment a subject of such importance demands. This article is a plea for definite, forceful experiments and demonstrations in hygiene comparable with the experiments and demonstrations so long deemed essential in physics and chemistry. The following experiments could be done in any secondary school.

1. *To demonstrate Bacteria in the Air.*—A test-tube of sterile nutrient agar was melted by immersing it in boiling water. The agar was then poured into a sterile Petri dish, where it cooled and solidified in a thin film. The cover of the dish was then removed and the medium exposed to the air for ten minutes. The cover was replaced and the dish set aside. Two days later, there had developed on the agar 63 colonies of bacteria. A dish prepared in the same way, but not exposed to the air, developed no colonies.

2. *To demonstrate Bacteria in Water.*—A test-tube of agar was melted and placed in water at 42° C., a temperature slightly above that of the human body. At this temperature, agar remains liquefied, but it is not hot enough to kill bacteria. Two tiny drops of drinking water were transferred to this melted agar by means of a small, sterile loop of platinum wire. The agar was then poured into a sterile Petri dish. A few days later, the dish was found to contain fourteen colonies of bacteria.

3. *To demonstrate Bacteria in Milk.*—In the same way, a test-tube of agar was inoculated with two tiny drops of milk, and the agar poured into a sterile Petri dish. In this dish 192 colonies developed.

4. *To show the Effect of Heat on Bacteria.*—Three test-tubes of milk were taken. The first was kept at room temperature, the second was immersed in water at 60° C., and the third placed in boiling water. At the end of twenty minutes, Petri dishes were prepared from each tube, with the following results:

Unheated milk	192	colonies.
Milk heated to 60° C.	13	"
Milk heated to 100° C.	5	"

5. *To determine the Effect of Freezing upon Bacteria.*—Two test-tubes of water were used. One was kept at room temperature, the

other was frozen solid by means of a mixture of salt and ice. At the end of twenty minutes the frozen specimen was allowed to melt. Petri dishes were then prepared from each, with the following results:

Not frozen	272 colonies.
Frozen	294 "

In a similar experiment with milk, 192 colonies developed from the sample kept at room temperature, and 193 colonies from the sample frozen.

6. *To show the Effect of Temperature on the Rate of Multiplication of Bacteria.*—Three test-tubes of milk were used. A Petri dish made from the milk at this time showed 80 colonies of bacteria. The first tube was placed in an ice chest, the second was kept in a locker, and the third was put in an incubator. Petri dishes made from each, twenty-four hours later, showed the following counts:

Ice chest (4° C.)	70 colonies.
Locker (20° C.)	30,000 "
Incubator (37° C.)	100,000 "

7. *To show the Effect of Drying on Bacteria.*—Three loops full of beef broth in which typhoid fever germs* were growing, were transferred to each of two dry, sterile test-tubes. Into the first tube, melted agar was poured, and then poured out into a sterile Petri dish. The drops in the second test-tube were allowed to dry, and a day or two later a Petri dish was prepared from this tube in the same way. The two Petri dishes showed the following counts:

Specimen not dried	6,000 colonies.
Dried specimen	0 "

8. *To determine the Effect of Sunlight on Bacteria.*—Two slips of filter paper were wet with a beef-broth culture of typhoid. The papers were placed in sterile test-tubes, which were sealed with paraffine to prevent drying. One of the test-tubes was placed in a locker. The other was exposed to sunlight for three hours. Petri dishes were then prepared, which showed the following counts:

Paper not exposed to sunlight	100,000 colonies.
Paper exposed to sunlight	0 "

9. *A study of Antiseptics.*—Four test-tubes were prepared, each containing 5 c.c. of water to which typhoid bacilli had been added. To the first tube nothing was added. Half a cubic centimeter of a weak solution of the antiseptic to be tested was added to the second. To the third, 1 c.c., and to the fourth 2 c.c. of the antiseptic. Twenty

* In repeating this experiment in high schools, harmless bacteria must, of course, be used. The colon bacillus is recommended for this purpose.

minutes later Petri dishes were prepared from each tube, with the following results:

Antiseptic.	0 c.c.	½ c.c.	1 c.c.	2 c.c.
5 per cent. Carbolic Acid	446	237	95	20
95 per cent. Alcohol	446	96	25	1
Salicylic Acid (Sat. sol.)	3640	298	60	15
$\frac{1}{10}$ per cent. Mercuric Chloride	3640	3	1.	0

10. *To disinfect a Room.*—Three slips of filter paper were moistened with a beef-broth culture of typhoid, and placed in large glass jars. In the first jar sulphur was burned. Into the second jar formaline vapor was passed. The third jar was not treated with a disinfectant. A few hours later, Petri dishes were prepared from each paper. They showed the following counts:

No disinfectant	100,000	colonies.
Sulphur fumes	6	"
Formaline vapor	0	"

11. *To show the Effect of Food Preservatives on the Rate of Multiplication of Bacteria.*—Two test-tubes, each containing 5 c.c. of fresh milk, were used. A Petri dish made from the milk at this time showed 83 colonies of bacteria. To one of the tubes about two grams of common salt were added. The second tube was not treated. The tubes were kept in a locker over night. Petri dishes were then made from them with the following results:

No preservative	7.520	colonies.
Salt	850	"

12. *To show the Antiseptic Properties of Gastric Juice.*—An artificial gastric juice was prepared by dissolving a little pepsin in a ¼ per cent. solution of hydrochloric acid. To 1 c.c. of this juice, ¼ c.c. of a beef-broth culture of typhoid bacilli was added, and Petri dishes made from the mixture at intervals for half an hour. The number of colonies developing on these dishes is tabulated below. To get an idea of the number of germs originally added to the gastric juice, the same amount of typhoid culture was added to 1 c.c. of sterile water and a Petri dish prepared from this mixture. The number of colonies on this dish is recorded as the count for 0 minutes.

0 minutes	35,200	colonies.
2 "	157	"
15 "	3	"
30 "	0	"

13. *To show the Antiseptic Properties of Human Serum.*—Under the supervision of a physician, a small amount of blood was drawn, by means of a hypodermic needle, from a vein in the arm. This blood

was placed in a sterile glass vessel and allowed to clot. After standing some time, serum separated. One cubic centimeter of this serum was placed in a small test-tube and five loops full of a beef-broth culture of typhoid bacilli were added to it. Petri dishes were made from this mixture at intervals for an hour. To get an idea of the number of germs originally placed in the serum, a control was run with 1 c.c. of sterile water. The count made from this control is recorded as the count for 0 minutes.

0 minutes	....	3,760 colonies.
2 "	....	737 "
8 "	....	410 "
15 "	....	34 "
30 "	....	2 "
60 "	....	0 "

12. *To show that Bacteria are not given off from a Moist Surface.*—A culture of harmless, brilliant yellow bacteria was smeared on the inside of a large glass tube. Through this tube a strong current of air was directed on to agar in a Petri dish. If bacteria were given off into the air from the moist surface, they would be blown upon the agar, where they would develop into colonies. The Petri dish used in this experiment developed no yellow colonies. The smear was now allowed to dry and was then crushed with a sterile glass rod. A second current of air was now directed through the tube into another Petri dish. This dish developed 240 colonies of yellow bacteria.

The above is merely suggestive of the kind of work that might be done in any secondary school. Most of these experiments could be performed by the average high school senior. All of them could be used as class demonstrations. Each one has a direct bearing on some large question of preventive medicine. A week's training in bacteriological technic will enable any teacher to give this work.

The experiments here outlined were suggested to me by Dr. W. H. Manwaring, and were carried out in the Pathological Laboratory of the University of Chicago, during the summer of 1904.

SHORTER ARTICLES AND CORRESPONDENCE.

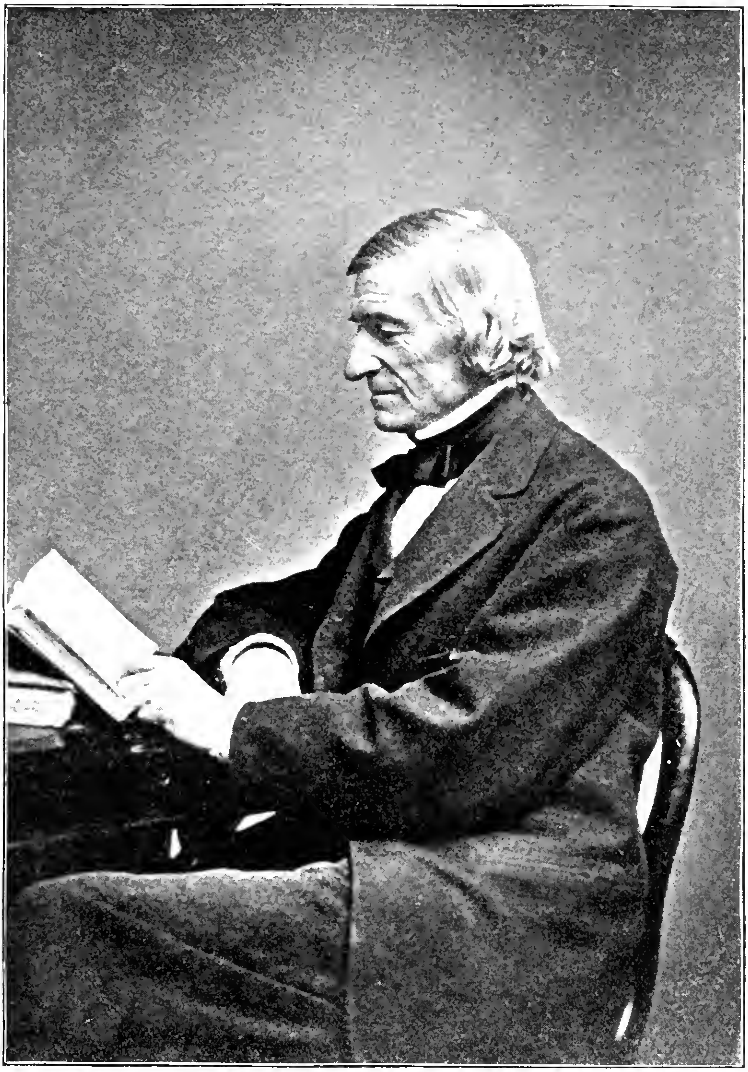
THE CENTENNIAL OF WILLIAM BARTON ROGERS.

On the seventh of December at the Massachusetts Institute of Technology, in a convocation of students and faculty, were held exercises in commemoration of the one hundredth anniversary of the birth of William Barton Rogers, the founder and first president of the institute. These exercises were of more than local interest, because the man in whose honor they were held has filled a great place in American education and American science. Born in Philadalphia in 1804, he passed his early boyhood and manhood at the old William and Mary College at Williamsburg, Va. In this institution his father was professor of natural science, and in the academic freedom of which this college was then one of the few exemplars, the young Rogers was able to follow the leadings of his own genius. He became professor there in 1828, and was transferred to the University of Virginia, in 1835, as professor of natural philosophy. His career in the latter place was one of great influence and power, not only as a teacher, but as an investigator. In connection with his talented brother he inaugurated the geological survey of Virginia, which survey has become almost a classic.

While living here and during frequent trips to Europe he became impressed with the need in America of institutions in which scientific studies might form the basis of education; and his removal to Boston, in 1853, was in large measure due to his belief that in this community was to be found a better opportunity for the founding of such an institution than in Virginia. Nothing which Mr. Rogers did could have more clearly indicated his good judgment than this conclusion, for there was certainly no community in America so ready for the building of a great technical school as Boston.

Here, amidst the stress of the years of the civil war and under all the discouragements which those years brought he founded the Institute of Technology, which forms to-day his greatest monument and which continued to be, until the very close of his life, his chief concern. He died splendidly, in the very act of service, at the Commencement of June, 1882, as he was addressing the graduating class. Combining as he did the charm of a gracious and pleasing personality with the power of an orator, of a great teacher and of an investigator it is not strange that those who have received their education in the Institute of Technology should have for him a reverence and an affection far above that which they entertain for any other man. In the truest and fullest sense the institute was founded by him, and in large measure drew its inspiration and life from his enthusiasm and devotion.

The exercises held on December 7 were simple, but full of tender regard for President Rogers and his work. An introductory address by the president of the institute dealt with a general estimate of the originality and breadth of Mr. Rogers's educational conceptions. President Lyon G. Tyler, of William and Mary College, told of the influence of that famous institution in the forming of Mr. Rogers's character and in the training of his genius. Professor Francis H. Smith, of the University of Virginia, spoke as an old pupil of Mr. Rogers and of his power as a great teacher. Professor Robert H.

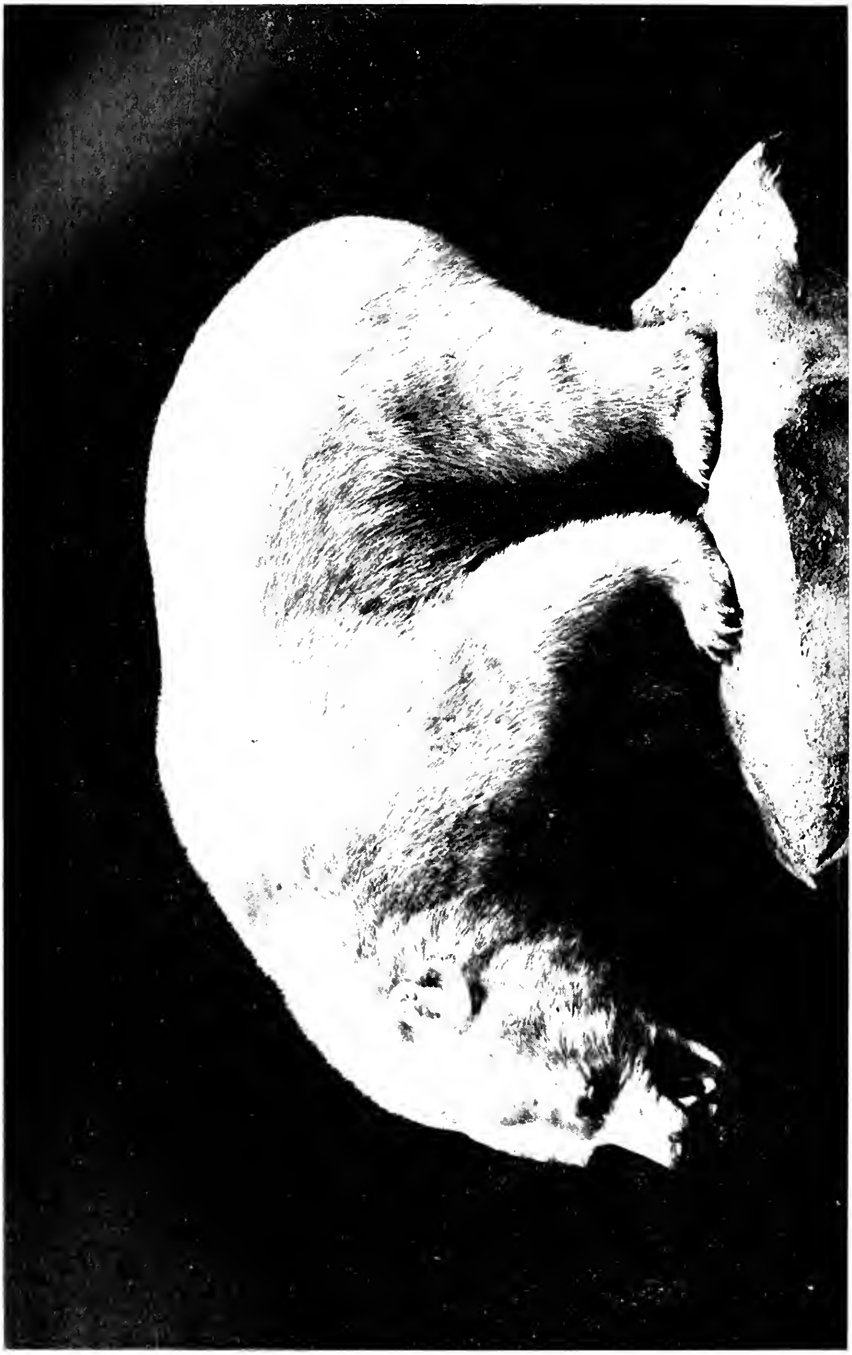


WILLIAM BARTON ROGERS.

Richards, a graduate of the first class of the Institute of Technology, related interesting events connected with the early beginnings of the institute.

At the close of these exercises an announcement was made that the corporation of the institute, out of funds in its control, had founded a scholarship of $300 yearly to be filled by a graduate or student of William and Mary College to be designated by the faculty of that institution. The exercises throughout were such as to impress upon the student body the nobility and loftiness of Mr. Rogers's character and life and to give a new estimate to those who knew him of the permanence and warmth of the memory in which he is yet held.

HENRY S. PRITCHETT.



Side View of the Inland White Bear (*Ursus kermodei* Hornaday), From a photograph of the mounted specimen in the Carnegie Museum, Pittsburg, Pa.

THE INLAND WHITE BEAR.

A FEW weeks ago the writer had the pleasure of welcoming at the Carnegie Museum his honored friend, Mr. Wm. T. Hornaday, the Director of the Zoological Gardens in Bronx Park, New York. Conversation turned upon the latest discoveries in the field of zoological research, and Mr. Hornaday announced that he had just described a new species of bear, 'The Inland White Bear,' to which he had applied the name of *Ursus kermodei*. After Mr. Hornaday had given the writer the substance of his article, which, as he said, would be read in New York on the evening of the very day we were chatting together, the writer asked him whether he 'would like to see a mounted specimen of the beast.' A look of surprise passed over his features, but in a moment he was piloted to one of the exhibition halls of the Carnegie Museum, and there he saw, what he least expected to see, a beautiful mounted specimen of the animal.

This specimen was acquired by purchase from Mr. Frederic S. Webster, the veteran taxidermist, at the time when his private collection was purchased by the trustees of the Carnegie Institute and he accepted the position of chief preparator in the Section of Zoology in the museum. For many years it has stood in a case and has been pointed out as an 'albino black bear.'

The story of its original acquisition by Mr. Webster may best be told in the words of Mr. Webster himself:

"A number of years ago the firm of Arnold, Constable & Co., of New York, purchased in the London market a lot of skins of the polar bear. I was at that time in business in New York and these skins, a dozen or more of them, were turned over to me to be made up into rugs. In the bundle I found the skin of this little bear, which I at once recognized as not being a Polar bear. I had never seen such a specimen before, but concluded that it was the skin ot an albino black bear. I purchased the skin and mounted it. The skull was with the head. The specimen was in excellent condition. The fact that the muzzle was black, and not pale in color, as would be likely to be the case in an albino animal, puzzled me at the time. The thickness of the woolly fur also attracted my attention, but having mounted the animal. I did not give the matter much thought afterward."

The specimen, of which a picture from a photograph by Mr. A. S. Coggeshall is herewith given, is thus far the only mounted specimen known to exist in any of the museums of the world. The skin is no doubt that of an individual taken in British Columbia, the home of the animal, which found its way into the London fur market from Canada. It was mistaken for an immature Polar bear, and was so classified by the dealer who sold the bundle of skins to the agent of Messrs. Arnold, Constable & Co.

W. J. HOLLAND.

CARNEGIE MUSEUM,
February 3, 1905.

THE PROGRESS OF SCIENCE.

THE CARNEGIE INSTITUTION OF WASHINGTON.

It is natural that the Carnegie Institution should claim frequent attention in a monthly report on the progress of science. Never before has there been an attempt on so large a scale to stimulate scientific research. The Royal Society of London; the Academies of Sciences of Paris, Berlin, Vienna, St. Petersburg and Rome; The Royal Institution of London, and the Smithsonian Institution, combined, do not have an income approaching that of the Carnegie Institution, nor have they the same freedom in the disposition of their funds. The third year book of the institution, which has just been published, is consequently a document of great interest to all those who concern themselves with the advancement of science. An artificial interest is further given to the annual report because the officers have hitherto followed the policy of not announcing until the end of the year their grants and appointments. An exception was of course made in the case of the president elected at the December meeting of the trustees to succeed Dr. Gilman; and we have already congratulated the institution and the research work of the country on the appointment of Professor R. S. Woodward, of Columbia University, to this important position.

It appears from the financial statement in the year-book that the disbursements for grants last year amounted to $267,232; for publication to $11,590, and for administration to $26,957. A reserve fund is being accumulated, $196,957 having been invested in railway bonds and there being a cash balance of $461,902. Appropriations have, however, been made for the current year that will exceed the income. They are as follows:

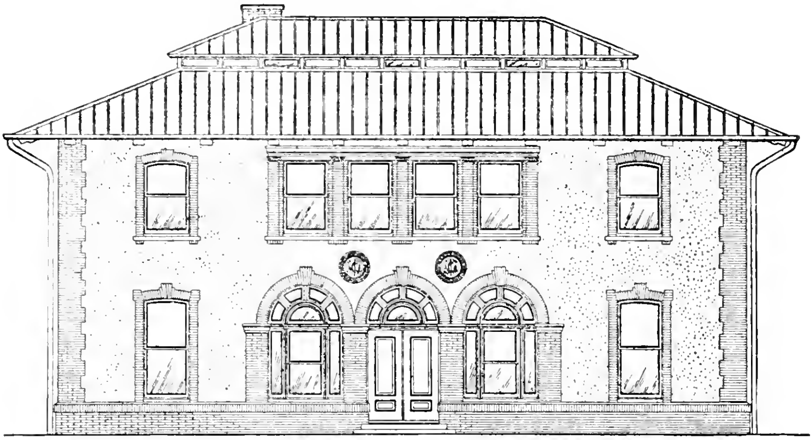
Reserve fund	$ 50,000
Publication fund, to be continuously available	40,000
Administration	50,000
Grants for departments and large projects	310,000
Grants for miscellaneous researches	168,000

The most important project undertaken by the institution last year was the establishment of a department of experimental biology. Dr. Charles B. Davenport, of the University of Chicago, was appointed director of a Station for Experimental Evolution at Cold Spring Harbor, Long Island, and

SEAL OF THE CARNEGIE INSTITUTION.

Dr. Alfred G. Mayer, of the Brooklyn Institute of Arts and Science, was appointed director of a Marine Biological Laboratory at the Dry Tortugas, Florida. A grant of $34,250 was made to the station at Cold Spring Harbor, and of $20,000 to the laboratory at the Dry Tortugas.

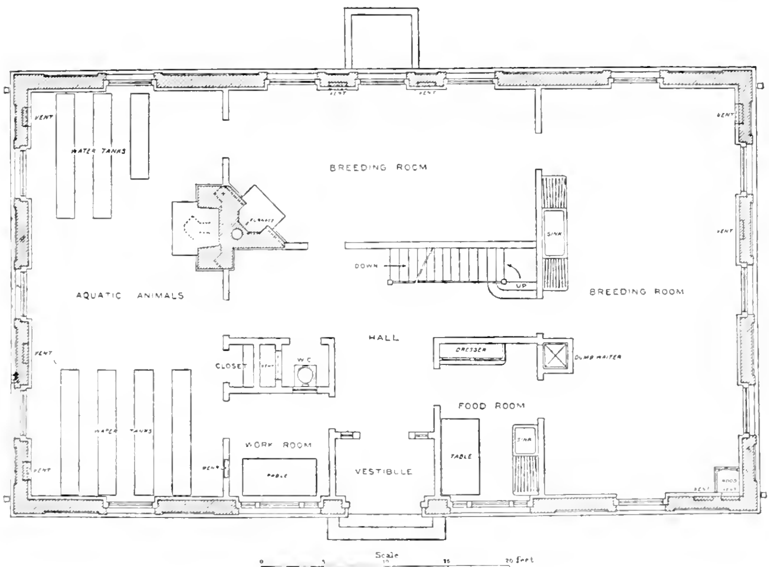
We reproduce illustrations showing the buildings of these laboratories and the yacht built for the southern station. A grant of $40,000 was made for tropical Pacific exploration, but it seems that Mr. Agassiz preferred to



STATION FOR EXPERIMENTAL EVOLUTION AT COLD SPRING HARBOR.

undertake the expedition without accepting the grant.

The other large projects are research in geophysics, in charge of Dr. George F. Becker ($25.000); a department of terrestrial magnetism, in charge of Dr. L. A. Bauer ($20,000); a Trans-Caspian archeological expedition, under Dr. Raphael Pumpelly ($18,000); a department of economics and sociology, under President Carroll D. Wright ($30,000), and a bureau of historical research, under Professor A. C. McLaughlin ($8,500). In the secondary grants, astronomy appears to have been favored. Professor George E. Hale received three grants aggregating $22,000, and, according to the daily papers, he has this year received a grant of $150.000 for a solar observatory on Mount Wilson. The next largest grants in astronomy were



SECOND FLOOR PLAN OF THE COLD SPRING HARBOR STATION.

$5,000 to Dr. Lewis Boss, Dudley Observatory, Albany, N. Y., for astronomical observations and computations, and $4,000 to Professor W. W. Campbell for pay of assistants in researches at Lick Observatory.

Several of the largest appropriations were made in bibliography: $10,000 to Dr. Robert Fletcher, Army Medical Museum, Washington, D.C., for preparing and publishing the Index Medicus; $7,500 to Ewald Flügel, Stanford University, for the preparation of a lexicon to the works of Chaucer, and $5,000 to Mr. Herbert Putnam, Washington, D. C., for preparing and publishing a handbook of learned societies.

Other grants as large as $5,000 were for the desert botanical laboratory, described by Professor Lloyd in the last issue of the MONTHLY, $5,000; to Bailey Willis, U. S. Geological Survey, Washington, for geological exploration in eastern China, $12,000; for the Marine Biological Laboratory, at Woods Hole, Mass., $10,000; to Professor W. F. M. Goss, Purdue University, for a research to determine the value of high steam pressures in locomotive service, $5,000; to Professor W. O. Atwater, Wesleyan University, for investigations in nutrition, $7,000; to Professor Arthur Gamgee, Montreux, Switzerland, for preparing a report on the physiology of nutrition, $6,500. Numerous smaller grants were made from $100 upwards, and twenty-five research assistants were appointed with stipends ranging from $1,000 to $1,800.

It is perhaps too early to express an opinion on the fruitfulness of the work of the institution. It appears that the large projects are more likely to yield valuable results than the smaller grants. The department of experimental evolution is certainly a useful undertaking, though we should prefer to see a laboratory established and left to develop as a separate institution on its own lines. The same is true of the solar observatory on Mount Wilson. Admirable work is sure to be accomplished under Professor Hale's direction, and an observatory should be established where the 'seeing' is the best. But the Yerkes Observatory was recently built and equipped with the largest of telescopes, and it seems unfortunate that it should be necessary for the director and part of the staff to be transferred at the expense of the Carnegie Institution to a new observatory in California, where there is already a mountain observatory of world-wide reputation. In most, though not in all, cases the secondary grants appear to have been safely bestowed, but usually for rather obvious and routine work, which might pro-

THE MARINE BIOLOGICAL LABORATORY AT TORTUGAS, FLORIDA.

THE PHYSALIA, THE YACHT OF THE FLORIDA STATION.

ceed nearly as rapidly without them. Money so expended is certainly not wasted, but it is doubtful whether it is used to the best advantage. We must acknowledge that in America we do not so much lack money and equipment as men who will devote themselves unreservedly to scholarship and research. How money can be used to produce and assist such men is a problem yet to be solved.

CLEMENS ALEXANDER WINKLER.

WHILE Germany has called a third chemist from outside the boundaries of the empire supposed to contain the greatest chemists of the world, the death of this truly great and truly German chemist must be doubly felt, and the earnest words of warning repeatedly uttered by him should make a new and lasting impression; for surely something must be amiss in the boasted perfection of German chemistry when Germany finds it necessary to call on Russia, Holland and Sweden to find chemists for the chairs in her greatest universities. A remarkable critical article—the last one written by Clemens Winkler—was printed in the January number of THE POPULAR SCIENCE MONTHLY; it forcibly presents the judgment of the discoverer of germanium on one of the dominant phases of chemical investigation of the present day, in which again German chemists are seen to occupy an extreme position, though they in this field also are merely followers, not originators. Since American chemists are wont to follow their, largely German, teachers, this critical paper deserves special attention in this country.

Clemens Winkler seemed predestined for chemistry. His ancestors for many generations were identified with the mining and smelting industries of old Freiberg; his father, Kurt Winkler, was especially prominent in this chemical industry and had been greatly favored as one of the last foreign students admitted to the private laboratory of Berzelius at Stockholm. The perfection of the analytical work of Clemens Winkler may be traced to this origin, which he himself was proud to remember, and which may also account for the fact, that some of his most critical analytical work was first published in the transactions of the Swedish Academy of Sciences.

Another favorable condition influencing Winkler's career was the fact that two of the most prominent men

CLEMENS ALEXANDER WINKLER.

of science of the Freiberg Mining Academy were his uncles, namely the great engineer, Julius Weisbach, and the renowned mineralogist, August Breithaupt. The greatest practical achievements of Winkler combine those two fields of investigation, namely, the manufacture of sulphuric acid by the contact method, from the waste gases of roasting ores, and the rapid and accurate analysis of furnace gases. His treatise on volumetric analysis is also specially excellent in its methods of reduction. Both these works have passed through three editions; his contact method was awarded a grand prize at the St. Louis World's Fair.

The discovery of the element germanium, by which Winkler has been known best throughout the chemical

world, also bears the mark of highest skill in both chemical and mineralogical sciences; for this element was detected in a very rare and always very thin coating of a silver ore occurring in but very few localities. Notwithstanding the exceeding scantness of the material, Winkler established the chemical character of the new element solidly by a complete study of its compounds and the production of the real element in the free state. Some of his original samples of this noted work could be seen in the German Chemical Exhibition at St. Louis this summer.

Clemens Winkler was born at Freiberg, Saxony, December 26, 1838; he became professor of chemistry there in 1873, and continued in this work with great success till his health failed in 1902, when he removed to Dresden, where he died after great suffering on October 8, 1904.

GREEK AT THE ENGLISH UNIVERSITIES.

THE ancient English universities are just now much concerned over the tide of modern culture that is surging about their borders. Oxford has voted to sit Canute-like, while at Cambridge the decision is yet to be made. The question has passed beyond the limits of the universities and is being actively discussed in the newspapers and magazines. The proposal that was rejected by a small majority at Oxford was to exempt from the entrance examination in Greek candidates for honors in mathematics and natural science, while at Cambridge the syndicate has recommended making Greek optional in the 'little go.' The teachers at Cambridge would probably vote for the change, but the question must be decided by convocation, the masters of arts who consist largely of country clergymen. There is no doubt as to the ultimate outcome, as the medical men and others having a scientific education will soon be more numerous than those who take orders. It should indeed be remembered that the English universities are, on the whole, less conservative in this direction than our own, for while they demand a classical school education for entrance, they do not require any study of Latin or Greek at the university for the degree of bachelor of arts.

In America we are concerned with the decision of Oxford, owing to the Rhodes scholars, who are now passing their first year of residence there. At the examination of the College Entrance Examination Board last year the largest number taking a paper in Greek was 176, whereas there were 351 in physics, 661 in French, 693 in German, 1,033 in English and 1,060 in mathematics. The selection of Rhodes scholars must be made from that one sixth of the students entering college who have studied Greek, unless the language is crammed for the examination. Of the representatives of the forty-three states now at Oxford, sixteen have entered for languages, thirteen for law and only three for science.

While the discrimination in favor of the classical languages and against the sciences at Oxford and to a lesser extent at Cambridge can not be approved by a scientific journal, and will probably be abolished in the near future, something may be urged in its favor. There is too great a tendency for our universities to lose individuality by making them places where everybody can learn anything. The newer English universities, such as London, Liverpool and Birmingham, are largely schools of science, and it might be wise to maintain one university based on classical learning. A home of lost causes and impossible loyalties exerts a certain commanding fascination over those who are subdued to its influence. From a wider point of view, there is something provincial in the attitude of a man such as Professor Jebb, who looks with contempt on the New Zealanders, because they are supposed to speak of 'Cupid and Sich,' while he himself is doubtless completely ignorant of the socialistic movement among

that people which in the future history of the world will exert an influence out of comparison with the pretty fables of antiquity. But in the widening current of democracy and the broader fields of modern culture room is left for those who cling to the classical traditions, and there seems to be no reason to desecrate their particular shrine.

SCIENTIFIC ITEMS.

We regret to record the death of Professor A. S. Packard, the eminent zoologist of Brown University; of Mr. William Sellers of Philadelphia, the well-known engineer; of M. Paul Henry, the French astronomer, and of Professor Ernst Abbe, known for his improvements of optical instruments.

Scientific societies that met at Philadelphia during convocation week elected presidents as follows: The American Society of Naturalists, Professor William James, of Harvard University; the Geological Society of America, Professor Raphael Pumpelly, of Newport, R. I.; the Botanical Society of America, Professor R. A. Harper, of the University of Wisconsin; the Society of American Bacteriologists, Professor E. O. Jordan, of the University of Chicago; the American Anthropological Association, Professor F. W. Putnam, of Harvard University; the American Physiological Society, Professor W. H. Howell, of the Johns Hopkins University; the American Psychological Association, Professor Mary W. Calkins, of Wellesley College; the American Philosophical Association, Professor John Dewey, of Columbia University.

The city of Berlin has arranged a competition for plans for a monument to Rudolf Virchow. It is to be placed at the intersection of Karl and Luisen Streets, a square which will henceforth be known as Virchow Platz.—The famous singing master, Senhor Manuel Garcia, of London, who invented the laryngoscope fifty years ago, will be 100 years old March 17, 1905. The London Laryngological Society and other societies have arranged a celebration which includes the presentation of a portrait by Mr. John Sargent.—The Danish government has issued a stamp bearing the head of the late Professor Finsen with the object of placing within reach of the poorer classes a means of subscribing to the national monument by which it is proposed to commemorate his work.

Professor Ernest Rutherford, of McGill University, has been appointed Silliman lecturer at Yale University for 1905. The previous Silliman lecturers have been Professor J. J. Thomson, of Cambridge University, and Professor Charles S. Sherrington, of Liverpool University.—Dr. Livingston Farrand, professor of anthropology at Columbia University, has been placed in charge of the work of the National Association for the Study and Prevention of Tuberculosis.

President Eliot, of Harvard University, has been elected a corresponding member of the Academy of Moral and Political Sciences of the Institute of France.—Professor Lewis Boss, astronomer of the Dudley Observatory of Albany, N. Y., has been awarded the medal of the Royal Astronomical Society.—M. L. Troost, honorary professor of chemistry at the University of Paris, is this year president of the Academy of Sciences in succession to M. E. L. Mascart, professor of physics at the Collège de France.

THE
POPULAR SCIENCE
MONTHLY.

APRIL, 1905.

THE MENACE TO NIAGARA.

BY DR. JOHN M. CLARKE,
NEW YORK STATE GEOLOGIST, DIRECTOR OF SCIENCE AND THE STATE MUSEUM.

FORECASTS by eminent geologists of the future of Niagara Falls have been much in the public eye and have lost some of their novelty though none of their interest. The great cataract, it is said, is committing suicide, and the physical factors which enter into the process have, it is thought, been carefully weighed. If matters proceed as they are now going, the face of the cataract receding without interruption, the falls are to wear themselves out, or if the dominating crustal movement continues, the escarpment is to be left bare because its waters will be stolen away and turned back into Lake Erie.

These are interesting possibilities, but they hardly rise to the dignity of probabilities, for opposing considerations have been left out of the calculations and even the remote periods assigned to their arrival grow longer and more distant in the face of factors overlooked or not sufficiently estimated. Nothing can be as wrong as mathematics or logic where the premises are wrong; nothing more excusable than the trial forecast for the life of a spectacular natural phenomenon, even though it will be and remain improbable till every factor in play has been given its full share in the process.

The problem of Niagara is not simple. As one sees with each change of the sun a new wonder in its fascinating rush of waters, so every reconsideration of the problem of its natural future brings into activity contributory and qualifying elements before unrecognized.

The intelligent public, now quite familiar with these forecasts, looks upon the Niagara cataract as doomed at some remote time and from causes which human power can not control, and doubtless this

feeling, now that the novelty of the sensation is past, has been followed by an intellectual resignation. Even the claims of posterity, the passing pang that our descendants may not see the mighty cadence of water as our eyes see it. quite relax all hold upon us in view of the fact that after all this may not happen just as represented.

The heavy bed of tough dolomite limestone at the crest of the falls, which is the occasion of their existence, lies above a thick mass of soft shale which easily caves in under the rebound of the falling waters, and by so doing becomes the chief cause of the breaking down of the crest and of the cataract's retreat. This bed of shale runs down into the earth in the direction from which the water comes, the south. It will be out of the reach of the cataract after a while, leaving an escarpment wholly composed of the tough limestone, which will make the problem of retreat thenceforward quite a different one from what it is to-day. There are, moreover, fifty-seven feet of hard dolomites above the crest of the falls over whose edges the water now descends in rapids. As the cataract moves southward by the falling away of its rock face it will grow higher instead of lower, until after it has passed the parting of the waters above Goat Island. Indeed it may become fifty feet higher than it now is and so firmly upheld by the heavy masonry of limestones that caving in must cease and further retreat will be reduced to its slowest terms.

As to the crustal movement whose tendency is to spill the waters westward out of the Erie basin, we may observe that the earth's crust is most uneasy and its movements most uncertain. Nearly every place is going either up or down, few are in a state of actual quietude. These movements have every variety of period; some may be secular, some are known to be relatively brief. Fifty years ago the shore at Percé on the Gaspé coast was going down, the fishermen had to abandon their drying stages and build them farther up the beach, but to-day the shore is coming up again and excavations for the new stages reveal the remains of the old ones which have been buried in the sea for nearly two generations. There is no knowing when the movement now affecting the Niagara region will cease.

Public resignation over the natural but distant fate of Niagara has grown to public concern at its immediate future. It is alleged that the present and contemplated industrial development at Niagara Falls immediately imperils the integrity and perpetuity of that great spectacle. Is this true? If it is, the American and Canadian public who hold this phenomenon in trust for the world ought to know it. However this question may be received and however answered by the interested producer or the disinterested public, it has on more than one occasion been flatly and formally before the people of the State of New York and of the Province of Ontario and has had to be met.

The legislative bodies of these two governments must meet it again, for it is plainly not the present temper of the public to let it pass in uncertainty.

Any citizen of New York or Ontario may justly take a pride in the magnificent industrial development building up about Niagara Falls, even though it is all at the cost of the beauty and magnificence of the cataract. Nowhere else has nature afforded such tremendous power at once available to mankind and calling forth the highest play of his genius. If I could hold a brief for the development of these natural resources it would be the delight of my pen to paint the wealth, the contributions to human comfort which will flow from them. I might argue that nature created this tremendous fall of water for the express purpose of contributing to commercial power and industrial supremacy. Such a brief would lament, as I have heard a distinguished engineer lament, the actual waste of power during the ages in which the great river has been discharging itself in unutterable glory and construe it sinful to neglect the opportunity so lavishly afforded. Such a brief might deride and cachinnate at the possibility of ever diverting enough water from Niagara to make the Falls palpably less, and all these arguments it would not be difficult to enforce with specious reasoning and pleading facts.

The attitude of the man who is willing and ready to see Niagara entirely drained for the wealth it would produce, and only a dreary canyon left to speak of its splendid past, is wholly intelligible, or would be except for the potent facts that wealth and happiness and contentment are purely relative and that the natural forces of the world were not created for the use of man.

The question I have put has been not only asked, but answered, in New York, officially. The abstraction of water from Niagara Falls was condemned by a committee of the constitutional convention appointed to investigate this subject in 1894, when the public had begun to suspect that the legislature had been too free with its gifts of franchises to power companies. It was vigorously and effectively answered by Governor Odell in 1904, who stood out finely against a tremendous pressure brought to bear upon him by the industrial interests, not through any hostility to them, but for the simple sentimental reason that the Falls must be conserved. Few know the courage of this act, but it was a triumph of sentiment and morality which the citizens of New York may well applaud.

The editor of the POPULAR SCIENCE MONTHLY has asked me to set forth the facts relating to the situation at Niagara Falls in such form that it may be made clear whether existing and impending conditions there constitute an actual menace to the cataract and its accompanying attractions, or whether public apprehension has been un-

necessarily aroused by a kind of pantophobia which may work a real injustice to industrial progress.

Except for that slender radical element of the community which proudly avows its willingness to see the Falls wholly developed into power all will agree that if danger is impending to the cataract it is time now that the danger be measured and fully apprehended.

The conservation of Niagara Falls is a question of public morals. Every industrial enterprise of wide scope has as its foundation a moral problem; it can not be simply the producer of great wealth regardless of the rights of others and of the higher claims of community life; nor can it ignore the claims of spiritual excellence and of the higher life which seeks something beyond the minted ideal. This claim of the higher life, the demands of the finer emotions, the love for the beautiful in nature, express themselves in part in the government protection of natural wonders from defacement and destruction; in organizations created to keep alive this sentiment and extend the ægis of the state over natural glories which belong to mankind rather than to men. No wise man confesses himself devoid of such emotions.

The violation of this moral principle in present practise offends the best sentiments of the race. It is said that the classic Falls of Lodore have been done to death by conversion into power. The far-famed Falls of Montmorency at Quebec show only a tremulous and weakened front to the traveler on the St. Lawrence, shorn of their glories in order to light the City of Quebec. The City of Rochester, seat of learning, refinement and industrial achievement, has exchanged the beautiful cascades of the Genesee for a slimy canyon. These attacks on natural phenomena have benefited the few, contributed to their comfort and convenience; they have injured the many, robbed them of a natural and proper heritage.

Under the guidance of this principle the claim of the individual, personal or corporate, must give way to the broadly founded rights of the community and the race. Under whatever political control such a majestic demonstration of nature's power may be, this control must be looked upon as a trust rather than the possession of a merchantable commodity or a commercial asset. States have not the moral right to do as they please with such phenomena. In a final analysis the individual or corporate claim to advantage from such a source is wholly extinguished, howsoever expediency may qualify and adjust the conflicting claims.

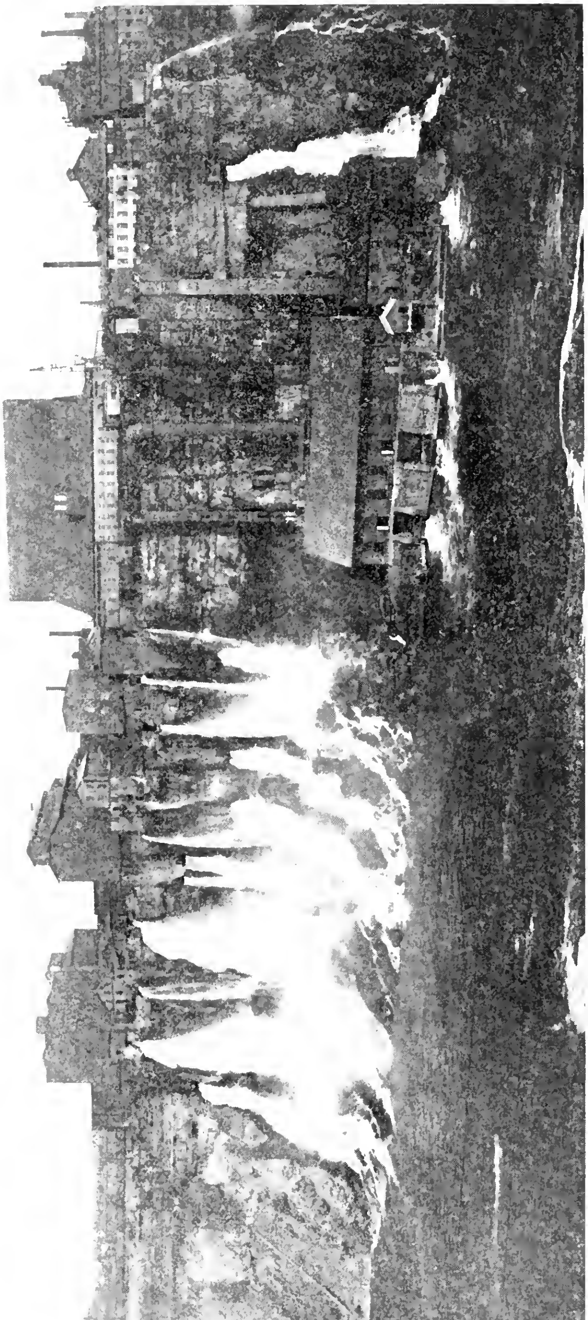
Wherein does the danger to Niagara Falls from industrial development lie? Simply in the drawing off of its waters from the river above the cataract, carrying them around the cliff by some other way or discharging them by tunnel into the face of the falls near the base.

The use of Niagara waters for power production has been the dream of years and its earliest successful achievement is expressed in the present Niagara Falls Hydraulic Power & Manufacturing Co., whose existence as an active consumer of Niagara water antedates its statutory recognition. The legislature of New York began giving away franchises to power companies about twenty years ago. It has never asked a financial return of any sort for any of these, as, during the

THE AMERICAN CHANNEL AT THE CREST OF THE FALLS DURING THE ICE JAM OF MARCH, 1903.

period from 1885 to 1894, when they were most freely granted, it probably seemed not wise to inflict a revenue on a budding industry. New York thus receives nothing whatever in return for the privileges it has granted for the consumption of its own waters. We mention this fact incidentally, just as we may mention that the Canadian companies are to pay a substantial return for similar privileges; but this matter of revenue has no bearing whatever on the theme before us. Whether or not any public revenue be derived from the use of Niagara is entirely beside the issue save as taxation of the product of the companies can be used as a means for the control of the situation.

Nine of these companies have been legally recognized or chartered in New York. Of these charters, all were granted in good faith, but it may be doubted if all were asked for and received in the same spirit. Some, it would seem, were immediately for sale as soon as



A View of the American Bank, showing the Power-House of the N. F. H. P. and M. Co., the Enclosed Tail-Races and the Growing Row of Structures at the Edge of the Water.

granted. Some failed to effect organization because the present requirements of such an undertaking demand enormous capital. Some were limited in respect to the amount of water they may abstract from the river, as the Niagara Falls Hydraulic Power & Manufacturing Co., to 462,000 cubic feet per minute, and the Niagara Falls Power Co., to 516,000 cubic feet per minute. Others were restricted in the amount of power to be produced, as the last named company, which may not exceed 200,000 horse-power. In most cases, however, no limitations were placed either on power to be produced or water to be abstracted. Several were limited as to the time in which they were to begin work in good faith, two of them to five years, two to

THE AMERICAN BANK BELOW THE STEEL ARCH BRIDGE, SHOWING THE WASTE OF WATER AND POWER FROM THE SPILLWAYS AND TAIL-RACES OF THE FACTORIES.

ten years. Three if not four of the charters are dead by limitation, one company sold its franchise to another, one is slumbering with an occasional show of life, another is leading a questionable life and two are producing and selling power.

The Niagara Falls Hydraulic Power & Manufacturing Co. and the Niagara Falls Power Co., the productive organizations, are alone to be credited with the really amazing industrial developments at this place, and they are still far within their statutory limitations in the consumption of water. With this superb display of mechanical achieve-

ment before his eyes one looks and looks in vain for a depauperated and enfeebled cataract. The flow of water is of course diminished, but to the occasional visitor it is but mathematically perceptible. Citizens of Niagara Falls who have the cataract daily before the eye have insisted that the loss of water is perceptible, and that such loss is felt in other ways is seen in the now annual gorging of the ice in the American channel at the upper end of Goat Island, which lays bare the American channel, sends all its water to Canada, and which very rarely happened when the depth of the water was normal.

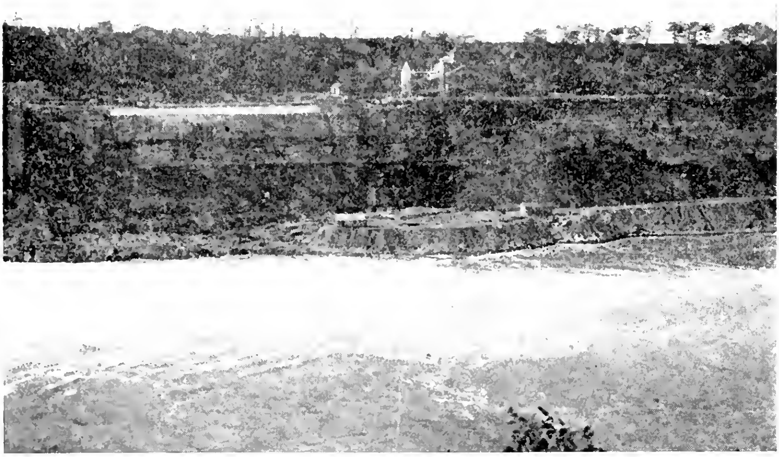
The two active American companies are not going to use any less water than now, but are vigorously increasing their output and building new power houses to meet their growing market. Indeed, one of them, realizing its close approach to statutory limits, has established itself on the Canadian side. These two companies are permitted to consume the following amounts of water:

Niagara Falls Hydraulic Power & Manufacturing Co.......	7,700	cu. ft. per sec.
Niagara Falls Power Co..............................	8,600	" "
	16,300	" "

The water abstracted by these companies is in no small degree wasted, that is to say the power produced is no equable measure of the amount of water taken from the river. This page carries a picture familiar to a thousand eyes—the view of the American bank below the steel arch bridge. This has been termed 'the backyard view of Niagara. The little cascades springing from holes in the side of the bank at various heights are the wasteways of the factories above. Some of these cascades are now encased in flumes and made productive at the bottom of the cliff, but this is only a recent change designed to save the wasted power, but involving the construction of a row of factories or wheel pits all along the edge of the water. The fall from the height of waters where these two companies have their intakes, to the base of the cataract, is approximately 224 feet, far beyond the working possibility of the turbine pit. The outrush of water at the base of the cliff near the bridge anchorage is the discharge of the great tunnel of the Niagara Falls Power Co., which is the tail-race from the wheel pits far back up the city and far above in the rocks.

On the Canadian side the activity in the erection of power works has been more strenuous. Utter devastation of the natural beauties of Queen Victoria Park, the demolition of islands and creeks, the excavation of the rock surface to the complete obliteration of well-known landmarks, have been the accompaniments of the unparalleled endeavors and achievements here. Whoever has visited this part of the Falls region since the beginning of these gigantic operations has sought in vain for the Dufferin Islands and Crescent Island, and what must have seemed to him an inextricable chaos of rock excavations, of

switches and sidings, of temporary and permanent constructions, in confusion worse confounded, has confronted him. Out of it all, it is presumed, the plans for the *artificial* beautifying of the spot will gradually unfold and the visitor of coming years is to see it with its attractions not only restored, but enhanced.



SITE OF THE POWER-HOUSE OF THE ONTARIO POWER COMPANY AT THE EDGE OF THE WATER BELOW THE FALLS ON THE CANADIAN SIDE.

Great sections of the river bottom, acres of rock over which the river has flowed for ages in tumultuous energy, have been for the first time exposed to the eye of man and the light of the sun. These sections of the river have now in large part been absorbed into fore-bays and intakes, into the permanent constructions of the companies, never to be given back to their proper charge.

The three Canadian companies are to be greater consumers than the American. They are the finest, the most magnificent conceptions of hydraulic engineering, and in their ultimate realization rise to proportions which are an expression of the genius that has inspired them. No one of these, let us remark, is moribund or inactive; each shows the highest type of virility.

The Canadian Niagara Power Co. has a statutory limit of consumption of	8,900	cu. ft.	per sec.
The Ontario Power Co.	12,000	"	"
The Toronto & Niagara Power Co.	11,200	"	"
	32,100	"	"

Adding to this total the limits of the American producing companies (16,300), we have for the entire chartered abstraction of the five companies referred to, 48,400 cubic feet per second.

This is of itself a dry and apparently barren fact. Let us look to its bearings upon the structure of the Niagara River and the total flow of waters through its channel.

The Niagara River flows over a rock bottom, on which the strata dip uniformly to the west. The sill or edge of the Falls is ten feet higher on the American than on the Canadian side, the waters at the crest of the American Falls ten feet shallower.

THE ROCK-BED OF THE RIVER ON THE CANADIAN SIDE, NOW PARTLY ENCLOSED BY PERMANENT CONSTRUCTION.

The flow of water through the channel and over the Falls was measured by the United States engineers in 1868, and by Sir Casimir Gzowski in 1870–3, with results varying from 246,000 cubic feet per second (the latter) to a maximum of 280,000 cubic feet per second (the former). The later averages given by the United States engineers, derived from the mean flow of water from Lake Erie at Buffalo during a period of forty years, afford 222,400 cubic feet per second. There are certain constants of abstraction for the Welland and the Erie canals which may be regarded as equalized by the inflow of streams into the river between Buffalo and the Falls, so that the figure which has been generally accepted and has entered into the calculations

of the engineers is 224,000 cubic feet per second. It is in cubic feet per second that we prefer to express our statements; the attempt to put them in terms of horse-power is attended with too many uncertainties.

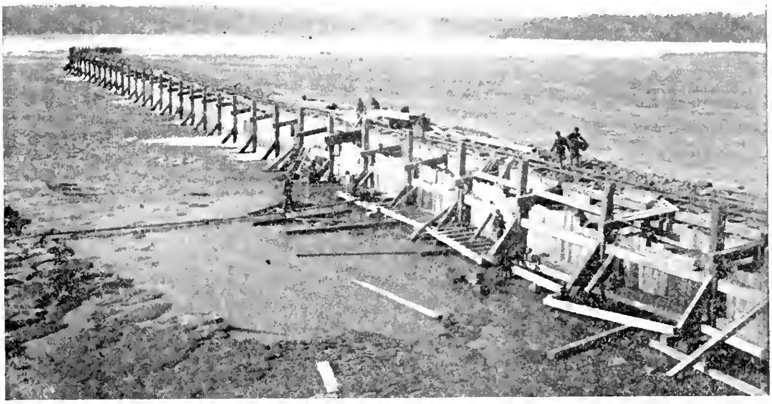
The potential or theoretical horse-power of this volume of water falling in the cataract is variously, sometimes carelessly stated in the engineers' reports as from three to six millions. A recalculation gives it at 3,800,000 for the cataract, which would be increased by the additional fall from the height of the rapids to the crest of the Falls. Goat Island, picketing the frontier, divides the waters unfairly, giving much more than three-fourths of their volume to the Canadian side,

THE ROCK-BED OF THE RIVER, LEFT DRY BY THE WING DAM OF ONE OF THE CANADIAN COMPANIES.

though the international boundary established by the Treaty of Ghent lies at the line of deepest water. Now as less than one fourth of the total volume of the waters pours down the American channel and this channel is much shallower than the other, it is at once evident that abstractions of water will make themselves first perceptible in the shoaling of the American channel. At the parting of the waters above Goat Island the great current of the river moves to the west, and converges into the funnel of the splendid Horseshoe Falls. The American channel actually carries in comparison but a feeble flow and the whole American cataract is in extremely delicate equilibrium.

A competent hydraulic engineer, taking the accepted volume of

the flow, the length of the entire crest of the Falls on both sides (4,070 feet) and the difference in elevation of the sill of the Falls, has calculated that when the flow is reduced to 184,000 cubic feet per second, or by 40,000 cubic feet, the water will be down to the present rock bottom at the edge of the American shore.



WING DAM OF ONE OF THE CANADIAN COMPANIES RUNNING OUT TO THE EDGE OF THE RAPIDS.

Then the American Falls, though still forming a cataract, will be but a ghost of their ancient magnificence; instead of the mighty sheet of emerald waters now spreading in silent majesty over the rock crest, a weakly, thin, white apron of waters carried forward by a slender impulse *a tergo* and the great cadence will have lost its glory. Electric searchlights in all the colors of the rainbow dancing up and over the falling waters and other factitious means of producing a spectacle will never compensate the loss.

Let one fifth more of the water be abstracted beyond the line we have already calculated and the American channel will be dry. That is, in effect, double the amount of 40,000 cubic feet, and when 80,000 cubic feet have been taken away from the present flow the Canadian channel will still be an interesting object, but the American Falls will be wholly gone.

All our figures in these statements and calculations, it may be well to repeat, are taken from the reports of the United States engineers, of the power companies' engineers, or have been specially derived at my solicitation by engineers of high standing.

We may return to the data given concerning present and immediately contemplated abstraction.

The two American and three Canadian companies now in opera-

tion or about to operate, when producing to their charter limits will abstract 48,000 cubic feet per second. That amount will bring the water-level to the bottom of the river at the American shore.

So much then is in immediate prospect. The turning of the waters a few days ago into the largest turbines the world has ever seen, thus inaugurating the actual production of Canadian power, sounded the death knell of the American Falls, leaving to those whose hearts sink and whose spirits shrivel at the thought of this destruction only a slender hope that it may be mechanically impracticable or commercially unprofitable to produce to the maximum amounts.

We are not permitted to stop with this forecast. One of the companies chartered by the legislature of New York and the last so chartered to abstract water from above the Falls, is the Niagara, Lockport & Ontario Power Co. It received in 1894 a franchise without restriction upon the amount of water it might use, but work was to begin in good faith within ten years. It was a modest organization with a slender capital, too slender, as it proved, to begin operations. It did nothing, but in 1904 came to the legislature of New York asking an improved charter enlarging its powers and extending its time. This company proposed to take its water from far above the cataract, as far back as La Salle, and not to return it to the river channel at all, but to carry it off overland by canal to Lockport, emptying it thence into Lake Ontario. The bill passed the legislature, not without commotion, but encountered trouble in the Executive Chamber. We have referred to the veto of this bill by Governor Odell as a fine act. Perhaps it is not necessary to say more, but the act was done in the face of most turbulent and insistent opposition, and it was clearly actuated by a relentless conviction of the higher rights of the citizens of the state. *Ex cathedra* statements by special attorneys and the company's engineers that no damage to the scenic features of the Falls could result, were supplemented by an offer of a tremendous sum to the state treasury for the governor's approval. The veto met with almost universal applause throughout the state. This veto was signed May 15, 1904. The company's old charter was signed May 21, 1894. There remained six days in which the company could get to work under its old charter. There is said to be to-day a slender ditch up south of Lockport, the work of a few men and a few carts, which represents the work done *in good faith* in the six days between May 15 and May 21, 1904. It has become a matter of common knowledge that this company has reorganized since these dates, increasing its capital enormously, and it is also stated that the stock has largely passed from the original organization into the control of one of the great corporations. It now looks as though this company means to do business if the courts have no objection, either

under its old charter or with a new one if it can get it. Its intentions and organization are not a negligible quantity in contemplating what is going to happen to Niagara. Should it succeed in constructing its canal and works it is not likely that with an unrestricted charter the company will consume less than 10,000 cubic feet of water per second, and if we assume this as a fair expression of its mean consumption we must increase the mortgage on the Niagara waters by this amount. It then becomes 58,400 cubic feet per second.

These are then the demands upon the river which are actually in sight.

In the seventh annual report of the Commissioners of the Queen Victoria Niagara Falls Park (1903), Mr. Isham Randolph, of Chicago, advisory engineer for the commissioners, makes, at the request of the board, a report on the 'Further Development of the Niagara River for Power Purposes,' in which he suggests sites for four additional companies to consume in total 29,996 cubic feet of water per second. We may better construe this proposed abstraction as operations under consideration rather than merely as work suggested. If we add the amount to our last figure the result, 88,396 cubic feet per second, leaves the entire American channel as dry as bone.

Such is the situation. We are out in the open with these figures. They are the figures of the engineers themselves. The counter-argument to these statements has been, so far as the writer's experience goes, either incorrect premises or a rather bored smile. Putting aside entirely the merely proposed developments and considering only those actually in process we see how closely we are brought to the dead line for the American cataract.

What are we going to do about it? A small, very small proportion of the community in New York and Ontario is content to let the process continue, even to the extinction of Niagara. This element of these communities is largely directly or indirectly concerned with the industrial developments there. Outside the boundaries of these trustee governments this percentage is greatly less. In the country as a whole, speaking for the general intelligent public, the opposition to this procedure seems so overwhelming as to be practically unanimous. New York long ago recognized the necessity of conserving such of these natural beauties as have fallen to her share and the state reservation at Niagara is one of the most beautiful of parks, lamentably small in view of the present encroachment, but upon it she has spent some millions of dollars. The Province of Ontario joined hands in this endeavor and the Queen Victoria Park was once and will be again a beautiful spot, all the more beautiful, the commissioners think, after the installment of the power companies is complete.

The president of the New York Reservation has stated that 800,-000 tourists visit the Falls each year. This is a vast number, bringing in an enormous revenue to the place. No other evidence is required to demonstrate how closely the interest of the whole world is focused on Niagara, for these visitors are representatives of every nation. How many hundreds of thousands will seek out Niagara when the world learns that the Delilah of commerce has shorn it of its glory? Will they traverse the seas to behold the wonders of a breakfast-food factory or of any other industrial triumph? These are everywhere; Niagara is

Commercial Niagara—The Canadian Bank below the Bridge.

unique. To make the problem equable, when will the power developments here put into circulation as many millions of money as do the visitors at the Falls? It is not good business to let the Falls alone?

There is widespread power throughout the country about Niagara, in central and western New York and in southern Ontario—not in concentrated and overwhelming manifestations, but power is running away now in many a stream which might be developed and stored without offense to the world and with profit to the community. While this power lying at our doors is neglected the apology for the desecration of Niagara lacks the ring of sincerity.

There should be a remedy for every public menace. If there is in the American people, especially in the citizens of New York and Ontario, a sturdy purpose to save Niagara, if it is proposed to meet the

problem and solve it, it will be found to possess difficulties enough. The working companies are established in their rights and entirely correct in their demeanor toward the state. The legislature of New York in 1904 memorialized the President upon the subject, urging the initiation of treaty relations with the King of Great Britain having for their purpose the cessation of further abstractions of water. It has been suggested by an influential newspaper that the end may be approached through a presidential commission which shall first determine how much water may be taken from the river without detracting from the scenic effects. Our figures show plainly and cogently that such procedure is useless because too late. They show that even the existing abstraction of water is qualifying the majesty of the Falls and that the contemplated authorized abstraction will carry the work of destruction well toward its finish. No more franchises are likely to be granted by either of the trustee governments. It may be well if these states or the superior government of each should enter into a treaty agreement to insure this result, but the danger-point being so near, in fact constructively passed, protection for Niagara means *control of power production*. The hope lies herein, that the companies, either through mechanical limitations, difficulties of cheap production or cheap transportation to a distant market, or through taxation of their product, may not be able to reach the volume of abstraction which is to seriously involve the splendor of the cataract. In this age of marvels, no present mechanical obstacles will long hold sway; the genius of man will overcome them all. In taxation of the power product, not necessarily for revenue but for protection, seems to me to lie the sole means of control of the problem, the only way of saving our national pride before the bar of the world.

SUNSPOTS AND WEATHER.

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IT is perhaps not far from the truth to say that the most pressing problem, as far as the daily needs of humanity are concerned, consists in finding some method of predicting the weather. Of the great value which a solution would have it is not necessary to say a word. Yet, in spite of many attempts, the chief problem is as yet unsolved. One may go a step further and say that there is at present no indication of any approach to a solution in the work which has hitherto been published. It is possible to forecast the weather with fair accuracy for a day or two in advance, but the methods by which this is done do not appear to have any bearing on the problem of predicting what the weather will be next week, next month or next year. The latter question must be approached in a quite different manner, and it is the object of this article to show the degree of success attained by one attempt to disentangle the wider fluctuations of climate which nearly every region of the earth's surface shows from year to year.

Weather and climate, like all other phenomena of nature, are nothing more than particular cases of the interaction of certain laws. Properly speaking, chance plays no part in their variations. That the motions of the atmosphere can be classed under well-known mechanical principles, there can be little doubt; that the various types of weather and climate are capable of being deduced from those principles with a sufficiently powerful method of analysis is equally certain; but whether such a method has yet been invented or is in process of being discovered at the present time is open to doubt, if we may judge from the very little that has hitherto been done in the direction of deducing the observed phenomena from the laws which govern them. The difficulties presented by this natural and logical process have caused meteorologists to turn to some other method of restoring order out of the chaos. Instead of deducing the phenomena from the general laws, attempts are being made to bridge the chasm which separates them by starting with the observations and trying to find out if some kind of order can be discovered—a support on which it may be possible to continue the bridge towards the opposite bank.

The procedure to be adopted when the latter method is used is sufficiently simple. Large numbers of observations of temperature,

barometric pressure, rainfall, etc., are made and recorded. We may use one of two methods to examine them. The first is to group the observations in various ways until we discover some group or groups into which the observations appear to fall. This method, however, entails such an enormous amount of labor that it has rarely been adopted. It is only successful in the few cases where the general nature of a group appears without much trouble. The second method is to assume that the observations must run in series which are repeated after definite intervals of time. These intervals of time are in reality obtained from the general physical principle that if any force is periodic, that is, if its fluctuations are repeated after a definite period of time, then certain of its effects are also repeated after a definite period of time, which is the same as that of the force. The first method is an attempt to construct the bridge by starting from one bank and building piers or supports on which the structure may be gradually extended across the chasm; the second method resembles a series of cables thrown across in the hope that they may be attached firmly enough on each bank to bear the weight of the bridge.

There is no difficulty whatever in attaching two of these cables to both sides. Whatever other causes operate, there can be little doubt that the sun must play some part in governing the climate of any particular place. The day and the year are therefore marked out beforehand as periods into which observations of temperature can be grouped, and these periods are fully confirmed. If the temperatures be recorded every hour out of the twenty-four for a large number of days, and the average temperature for each hour be formed by adding all the observations for that hour and dividing by the number of them, we obtain a series of twenty-four average temperatures. When the number of days on which observations are recorded is great enough, these averages will show a regular change rising to a maximum, for most places, in the early afternoon and descending to a minimum in the early morning hours. A similar method followed with the average temperature, say, for each day, will show a yearly period in the observations.

We thus get a series of average temperatures for each hour of the day and for each day of the year. But these are only averages and they only present regularity when very large numbers of observations have been used in forming them. At any particular time the difference of the actual temperature from the average temperature for that time may be as large or larger than the greatest difference of the averages during the period. It is evident then that other cycles must be sought which, by their combined effect, will give the actual temperature at any particular time. And what has been said about temperature can be said to a greater or less degree about the other phenomena, such

as rainfall or barometric pressure, which it has been customary to record. We find periods of a day and a year, but the differences of the averages from the actual observations are very considerable.

The next step consists in trying to find out whether cycles can be discovered in these differences, and for this purpose the same method is followed. But the periods to be examined are by no means obvious. The time of revolution of the moon, under the supposition that the moon has any influence, is not found in meteorological observations, or at any rate the effect is so small as to be negligible in comparison with what we want to find, and no other astronomical period seems very likely to find a counterpart in the records. There is, however, one period which at first sight appears to be a possible one in meteorological observations, namely, that known as the sunspot period. Before going into the evidence for its existence as a climate factor, it is necessary to say a word or two about the effects of periodic changes.

These changes may be roughly divided into two classes, those of short period and those of long period. From the former we should expect changes from day to day or every few days, constituting what we usually call the 'weather.' Nothing at all is known of the existence of any such period, all attempts to trace one having ended in absolute failure. The long period changes are in general those which affect the character of a season and which show the difference between one season and the next, or the variations which a given season of the year will show in several successive years. In countries where the most important interests are manufacturing and ocean transportation, the 'weather' is the first consideration; in lands where the agricultural interests are predominant, although the weather is important, it is more essential to have an idea of the climatic or seasonal changes. Thus if the sunspot period could be shown to have a large influence on the climate of any region, we should be able to forecast to a corresponding extent the general characteristics of future seasons, and lay plans accordingly. The practical value of such an investigation is obvious, but its scientific interest is not less if it leads to a more accurate knowledge of the laws of nature. The case therefore deserves examination.

In order to establish any connection between sunspots and meteorological changes, two things are necessary. First, the periods in which the sunspots can be grouped must be discovered and their relative importance determined. Second, the meteorological records over long intervals of time must be examined in order to see whether they exhibit similar cycles of change and whether those cycles, supposing that they exist, are sufficiently well-marked to be considered important factors in the variations of the seasons at any place from year to year.

Although the existence of sunspots has probably been known from

the earliest times, the fact that they undergo periodic changes in number and size was not recognized until long after the discovery of the telescope, and the law of the change was not determined with anything like accuracy until the middle of the last century. Accurate observations of their number and size were only commenced about 1830, but from about 1750 to 1850 enough material had been gathered to show that a maximum occurred on the average every eleven years. In the last two or three decades the use of the spectroscope has added greatly to our knowledge of their nature and motions, and the photographic camera has enabled astronomers to add permanent records of the state of the sun's surface at any time to the numerical estimates which were the chief contribution of the earlier observers. Such pictures are of special value whenever, as in the case of sunspots, much depends on the personal equation of the observer and still more on the particular method used in forming an estimate of them. Thus there is a period extending over the last seventy years in which continuous observations have been made, a period of another seventy years earlier in which the observations are worth discussing, although much less reliance can be placed on them for accurate deductions, and a still earlier period of about a hundred years from which a little doubtful information can be gleaned.

The net result which has been deduced from this series is an average period of $11\frac{1}{9}$ years between the maxima or times of greatest sunspot activity. But this average period by no means represents all the facts. The time between two consecutive maxima has been as long as 17 years and as short as 8 years, while some maxima are marked by much larger and more numerous spots than others. The average period between the minima or dates of fewest sunspots is rather less irregular, since it has never been known to differ by much more than two years from the mean period of 11 years. There is some evidence that these stronger and weaker maxima themselves run in a cycle, but the period is very doubtful. Wolf, who devoted most of his life to the investigation of sunspots, deduced a period of 55 years for this longer cycle, while there are later determinations of 65, $35\frac{1}{2}$ and 61 years. Further, the curves representing the number of spots from day to day or from month to month show many other irregularities which have up to now defied any attempt to group them in any regular order. Thus we have a well-marked average period of about 11 years and doubtful ones of about 35 and 60 years. These are therefore the periods into which the meteorological records are to be grouped in order to inquire whether there is any connection between the two sets of phenomena.

There is good reason to believe that a period of about 35 years is to be traced in certain of the meteorological records, and therefore it is

important to know how much dependence can be placed on the evidence for the existence of a similar period in the sunspot observations. In 1900 Dr. Lockyer took Wolf's sunspot numbers from 1833 to 1900; these numbers show six maxima and six minima of the average eleven-year period. But the interval from a minimum to the next following maximum is not the same for each of these six periods; it varies from 3½ years to about 4½ years. The six numbers representing these intervals were arranged according to their proper dates and it was noticed that they could be made to fit in with a periodic change of about 35 years in length. Again, the area of the sunspot curve from one minimum to the next was found, and another set of six numbers was obtained, the last five of which would again fit into a 35-year period. The two series corresponded well with each other if we excepted the first of each, the reason for the exception being that there was a doubt as to the observations from which the first number of the second set is obtained having been made on the same plan as the others. Unfortunately, the evidence thus presented is far from conclusive. There is nothing unnatural in the two series agreeing with one another as far as a period is concerned since they were deduced from the same set of observations. The difficulty arises in the attempt to find the length of the period from five or six numbers spread over rather less than two revolutions of the cycle. One would prefer to say that this result was a reason for further investigation rather than that it proved anything definite as to the existence of a 35-year period.

Far more numerous are the difficulties which beset an examination of the conditions on the earth's surface. In the first place, accurate observations are practically confined to the latter half of the last century, and these have been made chiefly in the northern temperate zones where the daily and weekly changes are apt to be very irregular and violent and where the local conditions frequently exercise much influence in determining the weather or climate of a particular place. To obtain averages free from these local and temporary conditions requires the examination of a very large number of observations extended over a long period. In the second place, the observations at one place should be kept separate from those at other places, for it is theoretically possible and even probable that a maximum at one place of observation may occur at the same time as a minimum at another place. For example, the yearly averages might show that a maximum rainfall in one place always occurred with a minimum rainfall in another, and *vice versa*. If the results from the two places were combined, a part or the whole of the periodic change would be lost. Then again, there is no clear indication what observations should be chosen for examination; average daily temperature, maximum or minimum daily temperatures, rainfall, number of violent storms, number of days

when the barometers or thermometers were above or below certain marks, and so on.

In dealing with any complicated problem it is usually best to try and simplify it as much as possible, and if the problem even then appears too difficult, to attack a special case, and this is undoubtedly the best plan to pursue here. In order to avoid the rapid fluctuations which occur in the temperate zones, meteorologists have turned to places in the tropics where the types of weather during the course of a year are apt to be much more permanent and where the changes from one year to another are likely to appear more clearly than in other regions of the earth. It seems to be generally agreed that, owing to its political and geographical situation, India is the country best fitted to satisfy these various conditions. The most marked peculiarity of its climate, taking the country as a whole, is a rainy season extending over some two or three months, with comparatively little precipitation per month during the rest of the year. Independently of the scientific side of the question, the quantity of rainfall and the duration of the rainy season are of immense practical importance, since a deficiency in either may and usually does involve a famine. An examination of Indian records may therefore be of great value; and as a fairly continuous series of observations at several observatories has been obtained for some twenty or thirty years, it may not be too early to commence a systematic examination of them.

Several investigations in this direction have been made lately, unfortunately with but little success in obtaining positive results. Here it is advisable to set forth with a little more detail what is meant by 'success,' since it is necessary to have a clear conception of the value, both scientific and practical, to be attached to the results of investigations based on the theory of averages. A set of observations is recorded and an examination of them is made with a view of finding out the existence of a cycle. Suppose that one cycle is found, but that its effect on any individual observation is very small. For example, if the temperatures at any particular place vary in the course of a year from 20° to 90° and we find a cycle running through all its changes in eleven years and having a maximum effect of 1°, the daily temperatures are scarcely altered if we subtract the amount corresponding to this long-period variation. Thus, though the cycle may be thoroughly well made out, it tells very little about the variations of temperature. It is only when we are able to get a sufficient number of periodic changes whose combined effect will fairly well represent the individual observations that we can be said to be at all successful in our analysis of the latter, and it is only then that a basis is found sufficient to predict the future numbers of the series.

Of the various attempts to trace long-period changes in the

meteorological records, only those will be taken in which some possible relation to the sunspot periods may exist. Thus a search is to be made for 11-year periods to establish a good connection; the 35-year period may furnish a possible connection between the two sets of phenomena, although, as we have seen, its existence in the sunspot curves is too doubtful to demonstrate the existence of the connection, while the 55- to 65-year periods, even if they exist in the sunspot curves, are too long to make a demonstration possible within the range of the recorded meteorological observations.

The best proof of the existence of an 11-year period has been furnished by Köppen, who showed that there was such a cycle in the combined mean annual temperature of many places within the tropics. But the total range of variation is only about three-quarters of a degree, while the mean annual temperatures show variations of from five to ten degrees. This appears to be the only well-established quantitative result with respect to the 11-year period. But several qualitative examinations have been made and the recent ones chiefly refer to rainfall and famine in India. Sir Norman and Dr. W. J. S. Lockyer have examined the rainfall statistics in India and Mauritius and they come to the conclusion that India has an increased rainfall near the sunspot maximum and Mauritius one near the sunspot minimum, and further, that the latter gives rise to a smaller pulse of rainfall in India. Thus India has two periods of increased rainfall, a large one near the sunspot maximum and a smaller one near the sunspot minimum. Unfortunately this investigation only refers to a single period of eleven years—from 1877 to 1886. They have also brought forward some evidence which indicates that the famine years occur between these two pulses of rainfall. The results do not seem to be sufficiently well made out to prophesy future famines with any certainty. Last year another writer showed a connection between certain Greenwich temperature records and the 11-year period, but the differences shown were very small. Other investigations on the same lines indicate about the same or a less degree of success in the discovery of a sunspot period.

In view of the doubtful existence of a 35-year period in the solar activity it is unnecessary to say much concerning a similar period in terrestrial phenomena. The most thorough investigation is that of Brückner, who examined a very large number of temperature records from all parts of the earth and deduced from the annual means a period of this length. But the amount of the change is only half a degree Fahrenheit, while the annual averages differ amongst themselves by from 5° to 10°.

In summing up briefly the results of the evidence hitherto presented, it must be admitted that no case has been made out in favor of a

definite connection between the number and size of the spots on the sun's surface and the weather or climate on the earth. On the other hand, theoretical reasons would lead us to expect some connection, and the evidence is rather in favor of it than otherwise; but it is highly probable that the direct effect of the spotted area is unimportant compared with the effects produced in our atmosphere by other causes.

Although a negative answer must at present be given to the question whether sunspots have any considerable share in the variations of climate, it would be leaving a wrong impression if no mention were made of a well-established 11-year period in the variations of another set of terrestrial phenomena. The state of the earth's magnetism has for many years been carefully recorded by suitable instruments and there is no doubt that its fluctuations correspond quite closely with the state of the sun's surface, not only in the cycle of long period, but also with respect to the minor variations. It can not as yet be stated that the appearance of a group of sunspots always causes a disturbance of the magnetic needle, but investigations have been published and others are still under way which appear to show a very intimate connection between them. Nothing is known as to the causes of this connection.

We have been dealing hitherto with only one exhibition of the solar activity. It is one which catches the eye and is perhaps well adapted to show the main features of this activity in somewhat the same way as the presence of snow and ice would indicate the higher peaks of a mountain range. Pursuing the simile, while it is true that we get an idea of the more prominent outlines of the mountainous region by noting the white places on the dark background, the latter would include many elevations and depressions which are never touched by snow, and we can not have a correct idea of the range without finding some method of observing them also. The case of sunspots is not very different. They probably form the bolder outlines, but, as Professor Bigelow has pointed out, they constitute but a sluggish register of the solar activity. There is another set of variable phenomena, known as the prominences, which are now supposed to furnish a much better index of the state of the sun at any time. These are elevations of the material of which the sun is composed, visible round the edge of the disc, and they appear to be huge masses of liquid or gaseous matter violently ejected from the main body. Unlike the sunspots, prominences are rarely absent and some of them can nearly always be seen on the edge of the sun's disc, so that by recording the number and height of those observable from day to day a much more continuous and accurate series showing the activity of the sun can be obtained. Moreover, it has been shown that the variations in the series correspond much better with those in the earth's magnetic force than

do the variations of the sunspot records. As yet, the number of years in which a continuous account of the prominences has been kept is too small to establish any good connection with the long-period or climatic changes on the earth's surface. It was only in 1868 that Lockyer and Janssen devised a method of observing them at times other than those rare ones when the moon comes in front of the sun's disc and leaves anything protruding from the edge of the latter in plain view for a few seconds. In general, large and numerous prominences are associated with the presence of sunspots, but prominences are frequently observed when no sunspots are visible in their neighborhood.

While this new method of noting the prominences in preference to the sunspots will probably improve our knowledge of what is going on in the sun, there is some tendency towards a change in the methods of observing the terrestrial atmosphere. The possibility of obtaining observations at heights of 2,000 feet or more above the earth's surface has directed attention to the fact that we are much more likely to get results free from local influences in this way, and perhaps a continuous series of such observations may show better any regular changes in the atmospheric phenomena. At the same time, the opinion has been strongly expressed that the observations already at hand should be sufficient to give the main features of the weather and climate if they can tell anything at all, and that it is time to stop the huge accumulation of records of temperature, rainfall, etc., and to undertake the thorough examination of those in our possession. There is undoubtedly great need for this: a plenteous harvest, with perhaps many tares and but few laborers.

In conclusion, while it is not my purpose to go into the reasons why more or fewer sunspots and prominences should affect our atmosphere, a few words may be said on the subject in order to counteract a widely spread misconception. Because the sunspots are dark areas, it is supposed—and one sees the statement frequently in the popular prints—that a portion of the sun's heat is screened off and the immediate deduction is made that 'cold waves' are the result. The first idea is very probably the exact opposite of the truth, and there is no theoretical or observed foundation for the second. As a matter of fact, it is generally agreed that sunspots and the associated prominences are evidences of increased activity, and therefore that they should denote a greater instead of a less output of solar heat. The amount of the change in the solar heat from time to time is as yet unknown; investigations in this direction are only in their infancy. Moreover, it is probable that the changes are too small to very materially affect terrestrial conditions, and even if they do so, the nature of the effect is quite doubtful. For example, an increase of heat from the sun may produce increased evaporation from certain water areas of the earth's

surface, and the moisture thus drawn up being carried away by the movements of the atmosphere, may be deposited elsewhere in the form of snow or rain. It is almost impossible without a much more intimate knowledge of the laws governing the movements in our atmosphere to say in advance what the effect of a slow and periodic change in the sun's heat will be. Although the change in any one year may be small, its effect on the earth in the course of a number of years may be cumulative and thus become very evident; or other circumstances, for example, a corresponding periodic change in the radiation of heat from the earth, may so counterbalance the change in the heat received from the sun that the effect of the latter is scarcely perceptible.

The conclusion of the whole matter has been well expressed by Professor Cleveland Abbe: that the key to the weather problem is not to be found in the sun or indeed in any external influence, but that the solution is to be worked out by the conditions which hold in the atmosphere itself—conditions which can only be discovered by a thorough examination of the internal laws of motion, quite apart from any external forces which may modify the results.

MEDICAL RESEARCH: ITS PLACE IN THE UNIVERSITY MEDICAL SCHOOL.*

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IF there be one word which is heard most frequently in the most intelligent circles interested in professional education to-day, it is the word research. In our own country in recent years medicine has fallen under its sway, and on all sides efforts are being made to meet its demands by the erection and equipment of costly laboratories within whose walls research may be carried on in a continuous and orderly manner.

Granted that the governing bodies of our great universities have familiarized themselves with the significance of this word and are giving it out, some only with the lips, others with a thorough conviction that to it must be accorded a permanent place in our higher institutions, the problem of how to deal with such a costly, and in many ways unattractive, offspring, how to correlate it with the teaching function, how to cultivate it side by side with the routine methods of instruction, will occupy a prominent place for years to come.

Research signifies effort directed toward the discovery of laws and principles through the systematic collection of new, and the better correlation of existing, data. It also means effort directed toward the more efficient and economical application of discoveries to the welfare of man, in other words, the utilization of latent and hitherto wasted energy. The aims of research are not culture, not miscellaneous information, not a mood of leisure meditation upon the origin of things, but mainly utility and service to mankind.

The chief influence at work in lifting medicine from a mere teaching to a research level is the same as that at work throughout the world of science and in fact in all intellectual fields. If we examine it more closely we find it akin to the breaking away from authority and dogmatism in religious affairs and from autocracy in the government of nations. Its foundations rest far down in the great liberalizing wave of the nineteenth century. We no longer believe that each step in advance is the ultimate one, but only one in a series toward ultimate truth, and this fact makes us realize that we must keep on marching.

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Research recognizes no immediate boundary to its activities, and no limit to its possible acquisitions. In placing only a temporary value upon its constructive plans and using theories only as aids to new facts, science grows in candor and modesty with its achievements.

In biology and medicine, the spirit of research takes into account the continual movement and flux in living things and their environment. It is a study of change, of transformation, brought about by conditions which may or may not be under experimental control. We describe carefully and minutely, not for the sake of the picture and its details, but chiefly to be able to recognize the change. Unless we know the consecutive pictures how can we detect the movement and its trend? It is the moving picture of the kinetoscope that has gradually replaced the single view in repose.

But there is danger that we may move too rapidly and find our advanced positions untenable. The world is just now very optimistic and expectations run high. If we give way to the feverish haste of our day, the slow, sure advance of medical science may be brought into discredit. For it is one of the features of this feverish haste to leave the position held as soon as possible for one more advanced. We move away because we have some doubt as to the security and trustworthiness of our present position, and we hope to gain by pushing beyond it rather than strengthening it. As a result of this attitude we find the thing most characteristic of the day and age is the rapid remolding of our stock of information. Revolutionary views are uttered from an inadequate basis of observational and experimental data. Theories become kaleidoscopic in their variety. Old views long since discarded come to the surface like old fashions. All this change and ferment is both the cause and the effect of the enquiring attitude of mind. Research begets new data and the opposition to these begets new research. Thus the fermentation is kept up and a froth several years deep lies on the surface which few can penetrate.

This haste and hurry is part and parcel of what might be called nature's lavish waste of energy. The volume of our information increases more rapidly than our knowledge of the principles which underlie and support it. The progress actually made is more apparent than real. It is a swaying to and fro with but little forward movement. Like the driftwood of which the waves are endeavoring to unburden themselves, many excursions back and forth must be made before the fact is finally landed. It is often much battered and barely recognizable.

That there is here a golden mean to be followed need not be emphasized. The spirit of research should be properly tempered by a true insight into the relation of enquiry to the great accumulation of knowledge and the reserve forces stored in the every-day experience of mankind and handed down from generation to generation.

In the meantime the optimism of the world which unknowingly assumes that medical science can rise above natural law and correct any and all excesses of individuals and communities must be met by a better education in natural science rather than abandoned to the manipulations of the charlatans of physical and mental healing.

Passing now to the more obvious external conditions which have tended to stimulate medical research, we may single out a few which have been of special importance. Perhaps the most ancient and strongest of all is the desire in the human breast to maintain health and prolong life. From its very beginnings the healing art has been weighed down with the greatest of problems, to save life and to cure disease, often in those of lofty estate, and its status for the time being frequently depended on its success or failure in accomplishing apparently the impossible. In our own day the crumbling of the formal religious belief that this life is but a preparation for that beyond the grave and the centering of our efforts to make it as much of a success as possible, the growth of wealth and leisure and the pursuit of sensual pleasure, these various motives, high and low, combine to exert a pressure upon medicine which is scarcely equaled in other professions. To save life, and to cure disease are imperative demands which grow more urgent, more impatient each year, and which suffice to quicken the efforts of the scientist and the true physician as well as the charlatan, and shape almost every problem which is considered worthy of attack to-day.

As a most important and timely contributory force to the advancement of medical research in recent years are the princely gifts of benefactors, with whom we especially associate the names of Johns Hopkins, Garrett, Fabyan, Rockefeller, McCormack, Payne, Morgan, Huntingdon, Sears, Stillman, and many others without whose aid medical research could hardly have commanded a corporal's squad to-day.

A factor not to be neglected in the advancement of medical science is the feeling of national pride. Most of the medical science of the past and much of the current knowledge has on it the mark 'made in Europe.' To-day this mark is occasionally being replaced by the label 'made in America,' and without doubt the home market will soon be well supplied. Fortunately, tariff barriers and trusts do not interrupt the currents of knowledge. Without hindrance we have filled our storehouses from the old world and I trust that we may repay in due time some of our huge indebtedness. Our national pride once awakened will see to it that our country, the wealthiest in material things, shall continue to give as well as to receive the fruits of the intellect.

These are forces acting chiefly from without. Perhaps the most

important acting from within has been the use of animals. The study of the great domain of infectious diseases has revealed such a similarity between the diseases of man and the higher animals that we hesitate now less than before to apply courageously the knowledge gained in our experiments upon the highest mammals to human physiology and pathology. Without this aid from animal life, medicine as a progressive experimental science would dwindle into insignificance. Moreover, the artificiality, the rigidity and awkwardness of the medicine of a generation ago have been largely dissipated by its contact with biology, which brought with it the comparative point of view.

Side by side with the use of animals we may place the convenient use of bacteria and other microorganisms in our laboratories in producing disease as one of the great levers of pathological research to-day. They have enabled the investigator to establish important centers of research completely independent of and coordinate with those connected with the hospital and the dead-house. The latter, it is true, still remains a final court of appeal for all discoveries destined for the relief and cure of human diseases.

In the historical development of science the research instinct appeared at first sporadically, and until recently it was simply the spontaneous flowering of the scholarly mind in the highest institutions of learning. To-day it has been actually organized not so much to train youth as to produce useful knowledge. This new organization of research has been greatly favored by the promise of valuable returns in the suppression of infectious diseases of man and animals. Most of the institutions founded thus far were created by public authority for this purpose. It was realized that such work must be pushed forward rapidly to secure results of value to public health and economy.

About twenty-five years ago special laboratories began to appear. Our own government figured among the earliest in voting what were then very liberal appropriations for the study of infectious animal diseases. At the same time came the German Imperial Health Office and somewhat later the Institute for Infectious Diseases in Berlin, and the Pasteur Institute in Paris; more recently there have been established the Institute for Experimental Therapy in Frankfort, Germany, and the many sero-therapeutic institutes and public health laboratories, nearly all of which have become noted for their research work. In our own country we have last but not least the Rockefeller Institute for Medical Research of this city and the Memorial Institute for Infectious Diseases in Chicago. Most of these were created to deal scientifically with problems of immediately practical bearing. But it does not need a prophet to foresee that following them others will arise which will devote themselves to broader and more fundamental problems and which will attack those left unsolved by the former institu-

tions. Of this latter class the Pasteur Institute in Paris and the Rockefeller Institute are conspicuous examples.

The founding of research institutes does not guarantee their success. That will depend upon the men who work in and for them. It has become evident that our research workers must have more diversified training than the older generation possesses. The store of knowledge accumulated by science must be made available to medicine. The only way in which this can be accomplished is to have trained men continually examining and testing this accumulating store of facts and applying them to the problems of disease. Such men should have medical training and approach their problems from the medical point of view; but to them should be spared the necessity of learning ultimate details of the medical art and they should give their energy to some sister study, be it morphology, physiology, chemistry or pathology. Medicine has just begun to realize the need of drawing to itself the great talent which hitherto has had an open door only to the pure and applied sciences. Research is largely dependent for its successful pursuit upon an attitude of the mind which insists on following a clew that promises to reveal some relationship, some law of causality between phenomena hitherto apparently unrelated. This type of mind has many of the attributes of the inventor who is attempting to combine to our advantage the forces of nature in new and unlooked-for ways and to express them in the form of labor-saving machines. In order to attract these minds we must pay them a living wage and provide workshop and tools, and exercise but moderate restraint over their activities. To them the exterior of practical medicine has a forbidding aspect. We must bring them to face its really wonderful problems through the portals of the laboratory.

After we have established research institutes and brought together a devoted, enthusiastic group of scientists we must not look too closely at the immediate practical value of research. Most of the epoch-making discoveries have had little, if any, direct influence on medical practise at the start and even for some time after. Some have wholly failed to yield hoped-for results, but they have had great influence in unexpected directions. This is chiefly because great discoveries are as a rule not ripe for use. To point out a hitherto unrecognized cause does not thereby enable us to overcome its effects. These may be grounded in centuries of adaptation. A great discovery frequently does no more than call attention to a new fact without defining its relationships. The discovery of the tubercle bacillus for example left the whole question of its complex relation to a given host untouched. The same may be said for most other microbes. The delicate equilibrium between parasite and host is the thing to be worked out before we can rationally proceed to upset it in our favor. There is there-

fore no need of hurrying to put discoveries to use. Many are discredited because of such ill-advised attempts and the investigator himself becomes discouraged in the futile effort to apply principles which fit only in part the practical condition to be influenced.

The tendency to make research directly prove pet theories, find short cuts to health, and cure diseases hitherto unsuccessfully treated will continue to give the investigator trouble for some time to come. What is needed is that at least a small number of scientists work at these problems of disease as we would at the other phenomena of the world around us. They should look them over from all sides calmly and objectively to get at the lessons expressed in them. They should look upon pathological manifestations as the normal sequences of causes operating under special conditions and for certain periods of time. They should endeavor to analyze phenomena rather than attempt to suppress or crush them. That function should belong to the health officer and the practising physician.

In order to take this calm attitude toward disease as a natural phenomenon and attempt to explain it, it may be necessary to move backward toward simpler problems from man to the higher animals, from these to lower types, from the complex processes of the human machine to the physical and chemical phenomena of the inorganic world. This has not always been the attitude of medicine, for standing as it does under the too near and impending shadow of suffering and death, it was but natural to attack the most difficult and complex problems first.

It is needless to say that the position of the research worker of the immediate future will not be an easy one. The strain to produce something is far more wearing than teaching. The mental play of the teacher's mind to produce something is relaxation compared with that of the investigator to carry out a contract for the delivery of new knowledge. The gap of years and even generations may yawn between the problem in hand and actual solution. It may indeed prove to be wholly impregnable from the point of attack. It may be solved by some obscure genius with slight facilities who happens to hit the combination which unlocks the secret.

We have all experienced the burden and complexity of growing information which has not reached the stage of actual knowledge. Extensive tables of figures are laboriously built up around it and the worker himself becomes encrusted and almost asphyxiated with methods and technicalities. We find the laboratory growing hot and stifling as we painfully add one more fact to the heavy burden. Suddenly and quite unexpectedly the true discoverer comes with a simple explanation. At his approach the air is cleared and freshened. Tables and figures are shoved to one side, and we begin our work once more with improved vision along another road.

Such is frequently the mission of the true discoverer, to leap over mounds of facts and figures, bring us back close to nature and show us that her movements are often far simpler than we dared imagine.

Thus far I have dealt with research as a thing by itself to be furthered by endowment and prosecuted by specially fitted men for the sake of its value to mankind. This is only preliminary, however, to the main thesis of our remarks, the training of research workers and the relation of research to the medical school. As a humble representative of the school which has provided so liberally in its new buildings for both research and instruction I must endeavor, amid the tangle of changing conditions, to place before you the relation between teaching and research as it presents itself to me.

I am quite inclined to make a sharp distinction between the physician and the investigator, and I think the time has come to create as it were a separate genus. What may be said of the type research worker should also apply to the teacher.*

Some enthusiasts would go so far as to urge that all students be made research workers. This is clearly uneconomical, for not many are fitted and the world has no use for many. There are needed chiefly well educated, humane, upright and patient workers who are ready to do the routine tasks of their profession. The physician must keep step with the great procession as it slowly moves forward. He can not deviate much to the right or to the left nor move much faster than the rest. His activities are more or less defined by a consensus of opinion. No matter how much he may swing his pinions in the laboratory, they will have but little room to move in the practical work of life. It is one thing to discover, and another to apply, one thing thoroughly to believe in our results, another to make others believe and act accordingly.

The research worker on the other hand deals more with the undefined boundaries of knowledge and with the frayed edges of sound information. He does not march with the procession, but he must do lonely outpost and scouting duties. He must seek clandestine meetings with those of other sciences, for he learns mainly by breaking through conventional barriers. He makes his discoveries unknown to others, and the farther they are in advance of the times the less attention they will receive.

* The time is not so distant when it will become necessary to separate the functions of teaching and research. The teacher will then investigate to improve his teaching, the investigator will teach to clarify the aims of research. One merges insensibly into the other. The attempt to set apart the teacher and investigator is simply another tributary of the current which is tending to make all teachers independent of the practise of medicine, by urging adequate compensation for their entire time.

Much confusion can be avoided, I think, by classifying laboratories into two categories, those that inculcate principles of medical science and those which subserve clinical diagnosis. In the latter, clinical medicine or medical practise seeks to lay hold of the acquisitions of experimental science and to utilize them in the interpretation of symptoms. The clinical or hospital laboratory approaches medical problems from the professional side and is thus an extension of medical practise into a territory where science and practise meet and shade into one another. Here the future physician should receive most careful training when he begins to direct his studies toward some branch of medicine. For this important stage the Harvard Medical School has left the fourth year open. In this year the student should utilize all possible means of combining his practical training with the more analytic methods of the laboratory and exploit whatever it may offer in more accurate methods of making and recording observations. At the same time, we must not make the mistake of calling this research. It may later on shade into research, but it is at first simply increasing and perfecting the means of identifying already well-known disease processes.

We are just now passing through a period of reaction against so-called book learning which is likely to lead us too far in the other direction. So much weight has been placed upon the training of the senses that we are in danger of neglecting the mind behind them. It is vaguely assumed by some that laboratory work is *per se* research. This is far from the truth. We might with profit carry on researches in the published work of others without entering the laboratory. We might, on the other hand, spend our whole life in a laboratory without acquiring more than a little manual and optical dexterity. We are in danger of forgetting that the training of the observational powers is simply developing another language made necessary by the expansion of medicine as a biological science. The true investigator may have but imperfectly trained senses, but he may still succeed in discovering and opening up a new country to us. With his intellectual power to grasp and arrange data, largely worked out by others perhaps, he finds his way through the unknown.

In our zeal to further the educational methods of the day, there is just as much danger that we overload the mind with too many sense impressions, as with too many facts gathered through the medium of books. Have we not heard of the absurd waste of time in some laboratories over work employing laboratory technique which is as empty as the written page to many a student? Have we not seen many a laboratory servant whose senses were sharper than ours on occasion; many a butcher who detected abnormalities of the tissues more quickly than we? Yet they were not 'doing research.' Let us not deceive our-

selves concerning the true inwardness of research. It does not consist in trained senses alone. It is a quality, an attitude of the intellect working through the senses. Claude Bernard clearly recognized this when he said: 'He who does not know what he is looking for will not lay hold of what he has found when he gets it.'

Though research may be carried on and is going on in all departments of medicine to-day, yet the true home of the investigator is the modern laboratory. Here we have a kind of reproduction in miniature of the actual field of work, where, by means of physical, chemical and biological methods of analysis, the problem in hand may be reduced to as simple terms as possible or at least confined within more or less governable conditions. When it has reached a certain stage of maturity, then facilities should be at hand which enable the investigator to approach cautiously the very complex conditions of actual disease in the hospital and its special laboratories.

The university medical school has thus two duties to perform, to train practical men, physicians and health officers, and to encourage the few who incline to research. The methods of training for both coincide for a large part of the course, but they must eventually diverge, the practical man to enter the actual field of conflict with disease and forge his weapons as well as he can from the storehouse of the world's accumulated experience and science, the investigator to continue his struggle with the stubborn and evasive facts of nature.

To carry out this program the university school must have teachers who are investigators, well-equipped laboratories both for large classes and for individual advanced workers. It must have satisfactory stables and operating rooms for small and large animals, for the experimental and observational study of animal diseases is the logical outcome of laboratory research. It is another intermediate station on the way to human pathology. It frequently presents such strikingly clear solutions of difficult problems and permits us to introduce the comparative method which has been so fruitful in the biological sciences. Closely associated with the school should be hospitals and clinical laboratories. Let us look at a few of these requisites very briefly.

The training and encouragement of research as well as thorough teaching in our medical schools lead by implication to the doctrine that professors should be investigators themselves. For the purpose of elementary class work it may be maintained that it is enough for teachers to instruct with the aid of all the paraphernalia of the day. But what shall they teach? Shall they go no faster than the successive editions of text-books allow, or shall they express an opinion about or actually teach the newest doctrines? As I stated before, the knowledge of the world is covered with the froth of research fermenta-

tion of several years' depth, and the latter yields about as much genuine knowledge as the froth does actual fluid. The teacher can not well sound its depths unless he has made some independent studies of his own. Then he will be able to say something definite, whether he has been at work in this very field or not. His critical view will enable him to take sides and be positive rather than negative in his teaching.

It will no doubt be maintained by many that to teach undergraduates the latest information is out of place or at any rate not necessary. All that they need for their daily subsistence pertains to fundamental conceptions. But I answer that we really know little of fundamental conceptions and what we believe we know is being affected and modified by every new discovery of any value. It is of the utmost importance that the theories which the graduate takes with him be as sound and withal as fresh as the teacher can make them, for they will form the scaffolding of his thinking for some time to come, possibly for many years.

The teacher who is called upon to direct the work of students who are beginning to feel their way into unknown territory or who have already left the beaten path far behind must of necessity be an investigator. Without going ahead of them himself his counsel is apt to be wavering and at times he feels himself wholly helpless to advise. In other words, to direct research the teacher must be playing the chief part while his students, of whatever rank, should take subordinate parts all definitely working toward a given end. Only by such cooperative coordinated work can both the worker and the task become a success. The teacher's capacity for research is not necessarily measured by his productivity. This may be curtailed by his high standards of what should be put on record. At the same time his capacity for research should somehow make itself felt through those whose labors he is directing. His fruitfulness should be manifested through them. If a teacher remains sterile both in himself and his students he has missed his vocation.

Of importance equal to that of an efficient body of teachers are adequate laboratory facilities both for teaching and research. Medical science has moved beyond that stage when a student could be kept profitably employed with a microscope and a box of slides. With the growth of laboratory methods of diagnosis, more varied and costly apparatus is needed, more space to place it and more laboratory service to guard it.

In research the demands are similar, but more exacting in certain directions. Some still believe that abundant space and work room with cases full of the latest instruments will certainly lead to great discoveries. These are, to be sure, necessary; but without the

motive power behind them they are more than barren; they create the debts rather than the assets of research. This motive power consists of enough assured income to carry on research and develop the research powers of meritorious students. There should also be ample means for laboratory service. Research is in one sense a business, the laboratory a workshop. Here all sorts of processes are under way and as no one would expect a workshop to be carried on with only a foreman, so a laboratory can not be kept in use without laboratory service. Hitherto assistants have been made the motive power and the laborers; but this system should no longer be maintained. Not only is it wasteful to fill the time of assistants with routine manual labor, but it is wasteful in so far as the laboratory is dismembered at the end of each year. Every laboratory should be in working order even if all assistants are lacking. The trained laboratory servant should represent the routine and conservative, the assistants and investigators the progressive, element.

With the growth of the cost of research it becomes of great importance to exercise care and selection in admitting men to research positions. Fortunately there are not many collateral attractions in a life of research and the process of elimination acts as a rule automatically. Still there is danger just now that some of the flotsam and jetsam caught in an eddy or else afraid of the current of practical life may seek the quiet of the laboratory, because of some imagined taste or capacity which fails to materialize later on. It is far better not to have any research workers than poor ones.

The leaven of research which has so completely permeated and revolutionized all doctrines and practises of medicine in the past quarter century is still acting and no one can foretell how it is going to mold the medical science and practise of the coming decades. No one can foresee what it is going to do with the medical schools.

There will come without doubt much change in the artificial boundaries of the present so-called departments. Created for purposes of teaching and administration, they are a veritable bane to the investigator who can not stop mining because his vein happens to dip into another man's superficial territory. Even in the routine of teaching many changes are likely to come. I believe there will be developments in two main directions. The present laboratory studies, or propædeutics, will be deepened and extended in the direction of the more exact sciences, or toward the physical, chemical and biological work of the university proper. As a necessary result of this movement much of the work now done by these departments will move forward into clinical medicine and surgery, and there will be a corresponding growth and strengthening of the clinical and pathological laboratories of the hospitals. To illustrate: Much of what is taught

to-day in pathology belongs to clinical medicine and surgery, for it is largely special and diagnostic in character. The pathologist is now the servant of the physician and surgeon in completing and rectifying their diagnoses. The pathologist of the future will deal with more general phenomena derived from experimental and comparative data, just as the physiologist has moved onward, or backward if you please, into general and comparative physiology. Similarly, the burden of other now scientific departments will be shifted into the more practical branches to make way for more fundamental problems. The logical outcome of such a rearrangement of studies would be eventually a college course arranged wholly with a view toward medicine and sanitary science, in which the bulk of the present early studies of the medical school would find a place, and, secondly, a practical course in medicine, surgery and sanitary science, in which clinical, hospital and public health laboratories would take a prominent part. It may be that in this way the time and energy of the student aiming for two degrees and a livelihood could be saved, while the efficiency and scope of the course could be increased at the same time.

The establishment of research institutes by governmental authority and private munificence marked the beginning of a new epoch in medical science by organizing research and giving it an assured status. The influence of these institutes upon research in the university medical schools will be watched with much interest. Unless the latter take a more definite position and furnish opportunity whereby investigations of a more serious and exhaustive scope may be undertaken, the research institutes will absorb the best men and the highest class of work and leave research as heretofore a by-product of the schools, often desultory, discontinuous and trivial. To avoid this impending calamity, the professors should be relieved of various routine duties incidental to the management of laboratory workshops. There should also be appointed investigators of definite rank whose teaching should be subordinated to research in such a way that the latter will not be seriously impaired by long interruptions.

In conclusion I wish to dwell briefly upon a phase of our subject which is perhaps the most important of all and toward which the various lines of our discourse have been converging.

The relatively large endowments given to medical education and research in recent years have created as it were a trust to be administered by the medical profession in the interest of human society in the broadest and highest significance of the term. This I interpret to mean that we must endeavor to make all advance in our knowledge of health and disease common property so far as this may be possible, to disseminate broadcast the benefits of research into the laws of health, so that they may enter into and form an integral part

of the life of the individual and the community. We all know that much of the daily work of the physician goes to charity, that the public health authorities and sanitary officers are but scantily compensated for their arduous and often dangerous labors. There can be no question that as a profession medicine stands at the head in disinterested service; but there is still room for improving the relation between medicine and the public. How can this be done?

Perhaps, next to the education of physicians of the highest standards, the immediate duty of the university medical school is the development through research of preventive medicine and sanitary science and the education of sanitary officers. This, it seems to me, is the best way in which our debt to society can be discharged; for it is the way through which medicine has moved during the past quarter century to its present commanding position; it is, in fact, the way of least resistance for the human race to evade or mitigate the penalty incidental to advancing civilization. Preventive medicine is the application of medical science to the mass as well as to the individual. It attempts to arrest disease before its momentum has carried it beyond the means of help. It is the truly modern as contrasted with the medieval point of view.

Nobody will deny that much has already been done in the development of preventive medicine and sanitary science. It will be claimed, and with justice, that more has been done than the public is willing and prepared to accept and live up to. We know that to-day municipalities continue to permit the unnecessary sacrifice of lives to epidemic disease, that politics is permitted to disorganize efficient boards of health in large and small communities and to put the best material interests of family and social life into untrained hands. We know that the public continues, in spite of warnings, to consume noxious drugs, widely and boldly advertised in the daily press. These difficulties are very real, but they should not discourage us. The medical profession is in a sense to blame for this condition; for the household remedies and cures of to-day are those of the doctor of a generation ago, and the medical practise of to-day will crop out in the daily life of the next generation. Likewise, the indifference of the physician and health officer of a generation ago is reflected to-day in the attitude of the mass of the people.

The university medical school has here a great function to perform, for it is the legitimate source of knowledge pertaining to hygiene and sanitation. There are few problems which have not been suggested by contact with disease. Sanitary science is broad and rests upon many foundations, and the means of disseminating its teachings are many, but its origin is in pathology. Without the stimulus of the

continual presence of disease its problems may become trivial and its practise ineffective.

The university medical school may in still another way hasten the diffusion of sounder views concerning health and disease by creating more interest among the educated in the general problems of pathology. This is but the obverse of physiology, and its principles once scientifically founded and objectively developed along general and comparative lines, should form an attractive study in all biological laboratories. We are still some distance from the realization of this suggestion, but the task is worthy of the best men in our best schools.

If we take this broad view of the work of the university medical school and try to put it into effect, medical science will come out of its somewhat isolated position and take its proper place beside the other sciences. The work of the physician will then be rated more justly, because the great complexity of the problem of health and disease will be more appreciated. His services will then be sought more frequently before rather than during the calamity of illness, because it will be better understood why he can more easily forestall and prevent than cure disease.

THE PROBLEM OF IMMIGRATION.

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AS has been pointed out, the extension of our immigration inspection service to the Canadian and Mexican frontiers, and the splendid work done on the border by the immigration officers, have closed the last gateways open to violators of our immigration laws. Not only are the laws enforced rigidly at United States ports and border towns, but by agreement with the Canadian steamship authorities, American officers are stationed at Quebec, Montreal, Halifax, St. John and Victoria, B. C., for the inspection of immigrants destined to the United States through Canada. Our present immigration laws are effective against many of the most undesirable classes of immigrants and our immigration officers by their vigorous enforcement of these laws have acquired a reputation in Europe which has a deterrent effect upon the undesirable classes. Every defective alien deported to Europe advertises the fact that we will not permit 'paupers, diseased persons or persons likely to become a public charge' to land. But the law at present is ineffective as applied to the class usually referred to as 'persons of poor physique.' They are admitted because it can not be shown definitely that they are 'likely to become a public charge.' They have friends, perhaps, who live in the city and vouch for their ability to earn a living, or their skill in a sweat-shop occupation is accepted as evidence that they will not become dependents.

In the immigration question, two great problems present themselves, the separation of the undesirable from the desirable classes, and the distribution of our landed immigrants. President Roosevelt in his message to the Fifty-eighth Congress, December, 1903, with characteristic directness, strikes to the heart of the question, and gives the following concise expression of its problems:

> We can not have too much immigration of the right kind, and we should have none at all of the wrong kind. The need is to devise some system by which undesirable immigrants shall be kept out entirely, while desirable immigrants are properly distributed throughout the country. At present some districts which need immigrants have none; and in others, where the population is already congested, immigrants come in such numbers as to depress the conditions of life for those already there.

This brings us to the question of what constitutes a desirable immigrant. The first requisite of a desirable immigrant is good physique.

Without a robust constitution and average physical strength, the immigrant can not cope successfully with the hardships which he will be called upon to endure in his new home. The immigrant of poor physique is not able to perform rough labor, and even if he were able, employers of labor would not hire him. The large employers of labor expect and demand men physically strong enough to do a fair day's work. The only place where the immigrant with a poor physique can make a living is in the large city, where he becomes either a parasite or a competitor of American skilled labor. The unfair competition of this type of immigrant can be better understood if one takes into consideration his standard of living and the system of sweat-shop production.

There is no longer demand for foreign skilled labor in the United States. Skilled labor in its ratio to unskilled labor among Americans has steadily increased until now the American skilled laborer can supply every demand, and each foreign skilled laborer who comes here comes as a competitor of our own workmen. On the other hand, the demand for unskilled labor is increasing in proportion to the decrease of American unskilled laborers. This demand will continue until our present industrial and commercial expansion ceases. New lands are opened up by settlement or by irrigation. Intensive methods of farming make possible a great increase of rural population, and this agricultural expansion creates an increased demand for manufactures. Thus our industrial and agricultural expansion progress side by side, and for this progress we must have plenty of brawn and muscle—unskilled labor. Americans can fill the requirements of the skilled laborers and mechanics, but if capitalists had to depend on native Americans for the unskilled labor necessary for their projects, these projects would never be carried to completion, or, if attempted, would be certain of financial failure.

The introduction of improved machinery, with its enormous effect upon our power of production, made necessary increased numbers of unskilled laborers and without these sturdy workers the use of machinery would not be successful financially or otherwise, and we should retrogress to the position of manual production which we occupied twenty-five years ago. Immigration and machinery are both charged with displacing American labor and depressing wages, but they are simply new forces demanded and made necessary by the expansion of our industries. To prohibit either is to paralyze industry, to stand still as a producing power, and to stand still is only the temporary pause before retrogression begins. Commercial prosperity is simply this expansion of industry and trade consequent upon the development of new resources. This development is the result of capital invested. Capitalists before investing invariably demand assurance that sufficient labor is forthcoming to carry out the proposed work, and that the compensa-

tion of such labor will be compatible with its financial success. If this assurance can not be given to capitalists, they will not invest, industrial expansion ceases, and the wages of the American workers, as well as of the aliens, suffer from general business depression.

In order to be a desirable immigrant, the type of immigrant represented must be necessary. As skilled alien laborers are no longer necessary, they can scarcely be classed as desirable. The necessity for the unskilled laborer will be conceded by those who take the trouble to study economic conditions.

The aliens of poor physique, who are usually skilled laborers, go to the crowded city, to the dark, poorly ventilated and disease-infected tenement. The thousands of these city dwellers arriving every year perpetuate the tenement house problem, and retard the work of sanitation and reform.

Of remedies proposed for the further exclusion of undesirable immigrants, three are worthy of consideration: (1) Raising the head tax, (2) an illiteracy test, (3) a definite standard of physique.

Raising the head tax to 100 or 150 dollars is suggested by some as a means of restricting immigration. This procedure is open to serious objection for several reasons. It would not be selective in its action. It would bar all classes, good and bad, indiscriminately, and would be almost prohibitive to the races with the best physique and highest percentage of unskilled laborers. In case of those who come here as home-seekers and who are able to pay such a tax, it would deprive them of a sum of money which would be of great value in their struggle, and much needed at the very outset of their new life. The imposition of such a tax is a weapon of defense which might be used in the event of great danger from immigration, owing to absence of demand for labor here, but that possibility seems remote and this high head tax must be considered as a last resort, not likely to be needed. A moderate head tax will probably be the rule for the next few years. The present head tax of two dollars may be raised to five or ten dollars in order to restrict the volume of immigration, if, in the opinion of our lawmakers, restriction of the quantity as well as the quality of our immigrants is necessary. Any head tax moderate or high can operate only as a numerical restriction and can not be expected to regulate the quality of immigration.

In order to appreciate fully the effect of barring illiterates, it is necessary to consider the proportion of illiterates in each of the principal racial factors of our immigration. Consideration must also be given to the percentage of unskilled laborers furnished by each of these races, because, although the illiteracy amendment is intended to exclude the parasitic city-dwelling immigrant, it affects as well a large proportion of the races furnishing us with the bulk of our necessary unskilled labor.

The following table indicates the ratio of unskilled laborers to the total landed in 1903, also the percentage of illiteracy; only those races whose illiteracy is above 10 per cent. are given:

Race.	Total Number Landed.	Number of Unskilled Laborers.	Ratio of Unskilled to Total Landed.	Ratio of Illiterates.
South Italian......	196,117	118,000	59 per cent.	48 per cent.
Pole	82,343	51,000	63 " "	32 " "
Croation	32,907	26,850	81 " "	35 " "
Slovak	34,427	21,400	62 " "	22 " "
Ruthenian	9,843	7,300	73 " "	49 " "
Lithuanian.........	14,432	9,550	66 " "	47 " "
Greek	14,376	9,700	68 " "	28 " "
Syrian...............	5,551	1,900	34 " "	54 " "
Hebrew..............	76,203	7,000	9 " "	26 " "

The first race (Italian) and the last three races (Greek, Syrian and Hebrew) given in the above table are notoriously city dwellers. The Italian and five races immediately following, Pole, Croatian, Slovak, Ruthenian and Lithuanian, furnish us with nearly all our unskilled industrial labor.

While it must be admitted that the illiteracy test would debar many thousands of undesirable immigrants and prospective dwellers in the tenements, it is doubtful if this result would compensate for the loss of 32 per cent. of such sterling laborers as the Poles, or 35 per cent. of the Slavs in general, in view of the fact that as large, if not a larger, proportion of the undesirable immigrants could be debarred by requiring a high standard of physique, without seriously affecting our supply of unskilled labor. The standard of physique should be definitely prescribed by law, so that the medical certificate of failure to reach the standard would be final, as it is now in loathsome or dangerous contagious disease, idiocy, epilepsy or insanity.

The standard required of recruits for the United States army, with a fixed minimum height and chest measurement, could be employed for this purpose. Every male immigrant between the ages of 18 and 45 should be required to pass such a physical test. Each family should be required to possess at least one male, supposedly the bread winner, who could come up to these requirements.

An aged person, if unaccompanied, should not be permitted to land, unless he or she possess a son, daughter or other near relative in America, who is willing and able to care for such aged dependent. This physical standard to be required of the persons specified in addition to, and not in place of, such other restrictions as are now in force. The requirement of a high definite standard of physique would have very little effect upon the most desirable alien races. It would fall heavily upon the parasitic and competitive classes, and, while it would not stop all the yearly alien reinforcement of the foreign quarters and

slums, it would at least ensure that the reduced number of additions were of a physique rugged enough to withstand the influences of such an existence. It would not materially reduce the number of agricultural and industrial unskilled laborers and would permit the admittance of plenty of men physically able to do a fair day's work for their employers.

In the matter of distributing aliens over a wider area, two distinct classes must be considered, the aliens already established in colonies in our cities, and aliens in general who, through ignorance of opportunities offered in different sections of the country, in many instances go to the congested areas rather than to the places where their labor is needed. No plan for the relief of tenement congestion, by better distribution of aliens already established there, can be successful without a reduction of the number of yearly steerage arrivals, particularly of those classes which tend to congest the cities. Many schemes for the distribution of the aliens congregated in cities have been proposed; some are chimerical, others more practical, but the consensus of opinion among philanthropic individuals and representatives of charitable societies is that the process of distribution is necessarily a slow one. The city-dwelling immigrant must be here some three or four years before he knows enough of our language and customs to enable him to be self-supporting away from his own race. It seems also that distribution must be effected individually rather than by colonies. The experience of the great Hebrew charitable societies at least bears out this view. Their efforts at wholesale rural colonization have almost in every instance failed, and the colonies established with few exceptions required the paternal aid of the society constantly. On the other hand, the same organizations have distributed several thousand Jews, who have been here some time and have learned something of American ways, in various parts of the country, and these have been almost uniformly successful. As has been said, some of the Hebrew colonies, which were failures as farming communities solely, were made self-supporting by the introduction of clothing factories. The establishment of such industrial colonies is of distinct service in relieving the congestion in the cities, and should be encouraged in spite of the claim made by some that the competition from the rural shop is ruinous to the clothing trade. From all that can be learned the clothing industry in New York can sustain its own low standard in competition with any number of rural shops.

When one considers how slowly the work of distributing the excess alien population of the tenement districts goes on in spite of the best effort of societies, individuals or municipal officers, the necessity is at once apparent either to stop altogether the annual reenforcement of this tenement population, or, at least, so reduce the number of addi-

tions that the work may make some progress. As it is now, the good work done each year by charitable organizations and by philanthropists goes almost for naught. The splendid work of the New York tenement house and street cleaning departments is nullified to a large extent by the yearly addition of thousands of these alien tenement dwellers, for whom the tedious work of education in sanitary matters must be repeated from the beginning.

In regard to aliens in general, whether they desire to live in the city or in the country, many believe that something should be done at the port of arrival to educate them in the resources and opportunities which exist in various states. The commissioner general of immigration, in his annual report for 1903, recommends that Congress appropriate a sufficient sum to establish information bureaus at the various ports of entry, located in suitable buildings where exhibits can be shown and information given to arriving aliens by government or state officers. Such information would enable the immigrant to locate where his labor was needed and where the best opportunities were afforded for making a home. This plan seems feasible and, coming from such a high source, is worthy of thorough trial. The commissioner-general, in the strongest terms, urges legislation to establish these information agencies, with or without the cooperation of the states, not only because of the need of the immigrant's labor in certain sections, but also because of the good effect upon the alien.

After all, these two problems of exclusion of undesirable immigrants and distribution of aliens are closely associated. The class that clings most persistently to the crowded city is an undesirable class. And if, because of its poor physique, the majority were excluded, as it would be if we had a definite standard of physique, our problem of distribution would be very greatly simplified.

It is scarcely necessary to refer again to the baneful influence exerted by the congested tenement areas, both upon the immigrant and upon the body politic. Here the immigrant receives false ideas of personal freedom and political privilege and a distorted impression of our whole political system. Moral deterioration is a certain accompaniment of life in the slums, and physical degeneration is still more marked. His occupation is parasitic in character or at best competitive from a standard far below that compatible with decent living. And while this deadly struggle for existence is being waged by the immigrant in the city, the farmers south and west can not procure enough labor to harvest their ripened crops. What a different story could be told of these poor aliens of the tenement could they be directed to the proper sphere! Removed from the temptations which surround them in the city, from the depraved examples of slum life which everywhere confront them, they would find in the country the healthy, moral stimulus of contact

with the soil. The demoralizing effects of over-crowding in the city would be neutralized by the pure air and invigorating influence of an outdoor life, and best of all, instead of being a diseased growth upon society, they would become producers, and each one would add his share to the sum of our country's wealth. Instead of absorbing false ideas of sociology and politics, the rural immigrant would have the opportunity of studying that bulwark of our institutions, the American farmer. What a different influence the honest, conservative farmer must exert over the alien immigrant from that of the ward boss of the city! How infinitely better as an example of citizenship for the foreigner's emulation!

Improved agricultural implements have removed much of the drudgery from the farmer's life. A profusion of good newspapers and magazines keep him in touch with the world, and his isolation is greatly reduced by the omnipresent telephone and trolley car. The rural mail delivery and the movement for better roads promise to reduce still further his isolation in the future. Thus the country will become not only more attractive to the inhabitants of rural communities, but it will also appeal more strongly to city dwellers. The present exodus of farmers' sons and daughters from the farms to the great cities will diminish in size, and the number of city-dwelling aliens migrating to the country will increase. In this great work of equalization of population many forces will combine and render mutual aid. The attractive features of the various parts of the country where labor is needed can be shown to the alien in many ways. Philanthropic societies and individuals are doing much at present and will do more in the future. The great railroad companies have a common interest with the various states, where the alien is needed and welcome, in distributing the alien and developing those states. The federal government can best combine and harmonize these forces by inviting their cooperation and furnishing an exposition building, as recommended by Commissioner-General Sargent, where the advantages offered by various sections of our country can be exhibited to the immigrants.

AGE AND EMINENCE.

By Professor EDWIN G. DEXTER,

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SELDOM has the popular mind been so deeply moved by the casual utterance of a savant as in the recent instance of Dr. Osler's now famous valedictory at Johns Hopkins. Nothing was probably more foreign to the speaker's mind than an intention to stir up the tumult of newspaper contention that followed his remarks, and we may presume that he is not altogether pleased at the exact character of the notoriety which he has achieved. The portion of his address that has brought him so prominently into the public eye had to do with the age of greatest usefulness in man, and runs as follows:

> I have two fixed ideas, well known to my friends, harmless obsessions, with which I sometimes bore them, but which have a direct bearing on this important problem. The first is the comparative uselessness of men above forty years of age. This may seem shocking, and yet, read aright, the world's history bears out the statement. Take the sum of human achievement in action, in science, in art, in literature—subtract the work of the men above forty, and while we should miss great treasures, even priceless treasures, we should practically be where we are to-day. It is difficult to name a great and far-reaching conquest of the mind which has not been given to the world by a man on whose back the sun was still shining. The effective, moving, vitalizing work of the world is done between the ages of twenty-five and forty—these fifteen years of plenty, the anabolic or constructive period, in which there is always a balance in the mental bank, and the credit is still good. . . .
>
> My second fixed idea is the uselessness of men above sixty years old, and the incalculable benefit it would be in commercial, political and in professional life if, as a matter of course, men stopped work at this age. Donne tells us in his 'Biathanatos' that, by the laws of certain wise states, sexagenari were precipitated from a bridge, and in Rome men of that age were not admitted to the suffrage, and they were called *deponati*, because the way to the senate was *per pontem*, and they, from age, were not permitted to come hither. In that charming novel, 'The Fixed Period,' Anthony Trollope discusses the practical advantage in modern life of a return to this ancient usage, and the plot hinges upon the admirable scheme of a college, into which, at sixty, men retired for a year of contemplation before a peaceful departure by chloroform. That incalculable benefits might follow such a scheme is apparent to any one who, like myself, is nearing the limit, and who has made a careful study of the calamities which may befall men during the seventh and eighth decades.

The thoughts expressed in these paragrpahs were much more fully elaborated by Dr. Osler in the delivery of his address, and we may

accept them as the basis of the controversy. It is plain that in the discussion of the second of the 'fixed ideas' the allusion to Trollope and the use of chloroform for the sexagenari was a bit of pleasantry and not intended by the speaker to be taken seriously. It has, however, proved too subtle for many a yellow sheet.

Yet it is just as plain that Dr. Osler in all seriousness believes that man's constructive period reaches its climax and begins to decline by the age of forty years and also that the world would be the gainer if all active participants in its affairs were at the age of sixty replaced by younger men. He does not, I take it, contend that men above that age are absolutely useless, but only relatively so. That is, for every man in service above the age of sixty, a better man could be found to take his place below that age. In considering this proposition it is inevitable that men, such as Gladstone, Bismarck, Moltke, Hoar, Rockefeller, Morgan and scores of others beyond the age limit, leaders in various activities, come to mind as refutations of his theories. Yet we must not forget that, according to the census, 6.4 per cent. of the inhabitants of the United States, or 4,871,861 persons, are beyond the age of sixty years, and that instances of aged leadership are comparatively rare—perhaps sufficiently so as to give some support to Dr. Osler's contention.

But it is the former of Dr. Osler's 'fixed ideas' that I wish primarily to discuss, the one expressed in the words that 'the effective, moving, vitalizing work of the world has been done between the ages of twenty-five and forty. We can not doubt that large numbers of thinking people are roughly of his opinion. Many corporations refuse to add to their working forces persons beyond the age of forty years, and a question recently taken up for serious discussion before a national body of educators was whether teachers did not as a class depreciate in effectiveness after the age of thirty-five.

It is not, however, through the expression of personal opinion that I can hope to add anything to the question, but through recourse to a considerable mass of data that I happen to have in my possession showing the age at which some thousands of Americans have received public recognition for services rendered. I refer to those mentioned in 'Who's Who in America.' Some years ago in connection with a study the purpose of which was to determine the educational preparation of those who had achieved the kind of eminence which mention in that book indicates, I made a tabulation of the ages of the nearly 9,000 persons mentioned in the edition of 1900. The names fell quite naturally, so far as vocation is concerned, into two twenty-five groups, the greater number of which—for men only—are given in the following

table, together with the number in each group, the median age of the group and the percentage of persons under the age of forty years.*

Profession.	No. in Group.	Median Age of Group in Years.	Percentage Below Forty. Years of Age
Actor	54	48	20.3
Artist	260	44	14.5
Author	523	54	19.4
Business man	200	63	2.5
Clergyman	655	59	5.5
College professor	1,090	47	22.0
Congressman	446	53	14.6
Editor	509	47	20.0
Educator	188	54	21.8
Engineer	284	55	9.8
Financier	215	64	5.5
Inventor	26	62	0
Lawyer	857	57	5.6
Librarian	362	50	22.6
Physician	540	56	11
Musician	111	44	33.3
Sailor	103	59	5.0
Scientist	146	44	31.3
Soldier	205	63	6.8
Statesman	202	55	8.0
	6,983	Av. 54	Av. 16

Although this table has a bearing upon the minimum age at which a certain sort of public recognition is given to achievement, in its consideration two things must be borne in mind; first, that many of those who were at the issue of the book over forty years of age performed the service which gave them prominence before they had reached that age; and, second, that there must always be something of a lag in public recognition, and in all probability many who had already performed service of importance had not yet been promoted to the ranks of 'Who's Who.' Yet, even with these qualifications, the figures are not without their bearing upon the question of the minimum age at which important public service is rendered, for without doubt achievement of the first rank is not slow of recognition. And the thing which must strike one most forcibly in any inspection of the table is the comparatively few men under forty years of age. Of the 6,983 men, the median age is fifty-four years, while but 1,118, or less than one in six, were below the age of forty years. Stated in other words, this means that in the year 1900 out of a group of nearly 7,000 eminent men but 16 per cent. were within Dr. Osler's age period of most 'effective, moving, vitalizing work.' Although this fact can not be taken as disproving his conten-

* The persons mentioned in the volume but not included in the group studied either formed a nondescript class so far as vocation is concerned or failed to give the date of birth, or were women and were tabulated separately.

tion, since, as has been said, a considerable number of the older men may have completed their important work at an early age, still it would seem to throw some serious doubts upon the truth of his generalization. At least the figures show that in a group of arbitrarily limited extent, *i. e.*, the size of 'Who's Who,' the young man in competition for a place is but a one to five 'shot.' But it is possible, through recourse to mathematics, to indicate approximately the age at which the service was rendered which secured admission to the book. To illustrate—of the entire number of 6,983 comprising our group, 86 were between the ages of twenty and twenty-nine years, the entire number having become famous during that decade of life. The probable mortality of that number of persons for the decade, supposing them to be good 'risks,' would be six. We may then suppose that 80 would enter the next decade. But our figures show that 922 of our entire group were between the ages of 30–39, inclusive, leaving the number 842 as representing the number of new names admitted during the decade. Of the total number for this age period (922), the mortality tables lead us to suppose that 78 will die before its completion, giving us 844 as the number passing on to the next group—that for the age decade of 40–49 years. Again we get the probable number added during the decade by subtracting the number thus admitted from the previous group, from 1,620, the total number of persons of the age covered by the decade and find the total number added for services rendered during the decade to be 776. In the same way, by using the continually increasing mortality rate and applying it to the number left over from previous decade-groups, we find the number added between the years 50–59 to be 376; from 60–69 years, 51. Beyond this point the computation gives us minus quantities for the number of persons admitted during each of the next three decades, indicating seemingly either or both of two conditions; first, that the mortality among these men of eminence is greater than that of the insurable risks upon which the mortality tables are based; second, that in the compilation of 'Who's Who,' the old men did not receive the recognition given to their younger confreres, thus reducing the size of these more advanced age-groups. Either one of these conditions would tend to bring about the statistical result alluded to, and on consideration we have reason to believe that both of them are active.

If the above reasoning is not fallacious, and if there is no great lag in the public recognition of achievement, we have a further refutation of Dr. Osler's contention that the 'work of the world is done between the ages of twenty-five and forty,' for we find the ratio of recognition for the several decades to be as follows:

20–29	30–39	40–49	50–59	60–69
3.9 per cent.	39.5 per. cent.	36.4 per cent.	17.6 per cent.	2.4 per cent.

From this we see, that although the decade from 30–39 shows the greatest productivity, it is but slightly greater than the next succeeding one, and that less than one half have made good—at least so far as public recognition is concerned—before the age of forty years.

Although these generalizations are for the whole group studied, irrespective of vocation, the first table shows considerable differences in the average age of those in the various professions and also in the percentages of those under forty years of age. This question was discussed by the author in the POPULAR SCIENCE MONTHLY for July, 1902, but I take the liberty of touching upon it briefly again.

It is noticeable that the musician distances all competitors in the race for distinction. This is not hard to understand when we recall the infant prodigies who frequently figure on our bill boards, or consider that nature has in most cases contributed more largely to his success than has nurture. Of those callings which presuppose a professional or at least an extended preparation, that of scientist seems from our table to promise the earliest recognition. This is perhaps due to the fact that with him the actual work of life is entered with a completer intellectual equipment than by most of the others, and that the period of preparation offers opportunities for research and original investigation which may bring renown even before life work is begun. This would also apply to the college professor with perhaps fully as much force and in a lesser degree to the librarian and the educator. These four then might be included in a class in which the period of preparation is extended, but for which work of a high order might be expected immediately on its completion and positions of some prominence aspired to from the start. Next in the race for renown come the actor and the author, almost neck and neck. If we conclude that nature had most to do with the musician's success and nurture with the educator's, we should be forced to place the author and the actor in a class in which these two forces divide the honors more evenly. No doubt one must be born an actor or an author to rise to a high rank, but after all, the making process is not to be despised as a factor, and this takes time. Except for the soldier and sailor, whose ability to rise to prominence, at least in time of peace, is determined by the rapidity with which those above him are retired from service, and the congressman and the statesman, whose minimum limit is prescribed by law, the rest of the vocations shown upon the chart fall, it seems to me, into a class for which the schools, as organized means of education, provide no adequate preparation, and for which that preparation must come to a great extent from the vocation itself. Thus the scientist, or even the college professor, who has devoted thirty years of life to study, can enter his profession from the top,

while the business man and financier for whom the accumulation of wealth is a desideratum, or the lawyer and the doctor who must command a practise, or the minister who needs a congregation, must with the same period of intellectual infancy enter it from the bottom and devote a few more years to the climbing process. In so far as the physician is an investigator, the conditions of the scientist apply to him, and no doubt the considerable number who are such accounts for the fact that his recognition comes earlier than that of his competitors in law and the pulpit. The surprising thing of the figures is perhaps the slowness with which the inventor gains a foothold in the ladder of fame. Not one of those mentioned was below the age of forty years, though the group is too small to give this fact much weight.

Although women are not included in the table given, the study of those mentioned in 'Who's Who' shows that upon the stage and in musical circles recognition is much earlier for them than for men, while in all other callings it is slower. This would seem to suggest that attractiveness of person is at a greater premium with her than with her brother, and perhaps makes up for some other defects. When however this is outlived with youth, the struggle seems to be a hard, if not a losing one.

AUTHORITY IN ENGLISH PRONUNCIATION.

By Professor EDWIN W. BOWEN,

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FOR wellnigh two centuries a popular belief has prevailed throughout the English-speaking world that there should be a standard of pronunciation, which should be followed in all those countries where English is the native tongue. Many people, holding this view, assume that some such norm is unconsciously observed by men of education and culture, who, because of their influence and rank, are generally conceded the right to establish the customs of speech. It is but natural, therefore, that men with greater or less claim to culture and education should take it upon themselves from time to time to determine the supposed standard of pronunciation. Thus as far back as the beginning of the eighteenth century we find that the orthoepists of that period undertook to ascertain and record the pronunciation of English as practiced in polite society.

Now, the early orthoepists discovered, apparently to their astonishment, that English pronunciation, even in the most cultured circles, far from being fixed by ironclad rules, was quite an elastic thing, allowing considerable latitude. Indeed, two centuries ago pronunciation in English, as reflected by the best usage, was no more uniform than it is to-day. Then as now, men recognized no fixed and absolute standard of English pronunciation. They followed their own tastes and individual preferences, despite the orthoepical suggestions and recommendations of their contemporaries. Prejudice and caprice, too, in those days, as in the present time, were factors to be reckoned with, so that the path of the would-be authority on pronunciation was beset with no slight difficulty.

It must not be inferred, however, that the orthoepists themselves were a unit and in perfect harmony as to current usage. On the contrary, they were frequently far apart in recording the pronunciation sanctioned by the best society and differed quite as much as their worthy successors of the present day. They sometimes indulged in vituperation and severe censure at each others' expense and made no attempt to conceal their disapproval of a rival's authority, which they expressed in plain, vigorous Anglo-Saxon. Some of their sarcastic remarks furnish spicy and entertaining reading to the student who is willing to plod his way through the dreary waste of those forgotten dust-covered tomes.

The most conspicuous among the eighteenth century orthoepists were Baily, Johnson, Buchanan, Sheridan and Walker. Some of these were Scotch, and some Irish, and some, of course, English. Quite naturally it struck the fancy of an Englishman as somewhat humorous, not to say absurd, for an Irishman or a Scotchman to pose as an authority on English pronunciation. So the damaging taunt of foreign nationality and consequent lack of acquaintance with English usage was flaunted in the face of Buchanan and Sheridan, natives of Scotland and Ireland, respectively.

When Doctor Johnson was informed of Sheridan's plan of producing an English dictionary that was designed to indicate the pronunciation of each word, he ridiculed the idea of an Irishman's presuming to teach Englishmen how to speak their native language as utterly absurd. "Why, Sir," growled the autocrat of eighteenth century literature, "my dictionary shows you the accent of words, if you can but remember them." Then on being reminded that his dictionary does not give the pronunciation of the vowels, "Why Sir," continued he, in his characteristic surly manner, "consider how much easier it is to learn a language by the ear than by any marks. Sheridan's dictionary may do very well; but you can not always carry it about with you; and when you want the word, you have not the dictionary. It is like the man who has a sword that will not draw. It is an admirable sword, to be sure; but while your enemy is cutting your throat, you are unable to use it. Besides, Sir, what entitles Sheridan to fix the pronunciation of English? He has, in the first place, the disadvantage of being an Irishman; and if he says he will fix it after the example of the best company, why they differ among themselves. I remember an instance: when I published the plan of my dictionary, Lord Chesterfield told me that the word *great* should be pronounced to rhyme to *state;* and Sir William Yonge sent me word that it should be pronounced so as to rhyme to *seat,* and that none but Irishmen would pronounce it *grait.* Now, here were two men of the highest rank, the one the best speaker in the House of Lords, the other the best speaker in the House of Commons, differing entirely."

As this quotation shows clearly and forcibly, even the usage of the very best speakers in England in the eighteenth century was far from uniform and harmonious, as has been intimated in the opening paragraph. Moreover, it is evident from the striking illustration Johnson uses that English pronunciation must have varied much more two centuries ago than it does to-day: for no two speakers of national reputation, such as the leaders of the two chambers of Parliament presumably must have been, would differ so radically at the present time in their pronunciation. The truth is, in those good old days men paid but little attention either to pronunciation or to spelling. It is a

fact not so widely known as it deserves to be, that English orthography two centuries ago was just emerging from a state of confusion and chaos; and law and order were then for the first time beginning to appear. The result is the conventional spelling which only since the eighteenth century has been stereotyped in the form now so familiar to all educated people. And not even yet, as we know, has English orthography had its perfect work. As late as Doctor Johnson's time, the spelling of many English words had not yet been crystallized, and not a few words could be spelled in two distinct ways, either of which was recognized as correct. For instance, the spelling of *soap, cloak, choke* and *fuel,* to select only a few examples, as recorded in his dictionary, vacillated between 'sope,' 'cloke,' 'choak,' 'fewel' and the present accepted spelling of these words. These variant spellings, long since rejected, now seem to us either attempts at phonetic spelling or quaint and curious imitations of Chaucerian orthography. Having discussed elsewhere* the subject of English spelling, I dismiss the matter here with this passing reference.

The crystallized form of English spelling which has been brought about mainly through the influence of the printing-press in the last few centuries we accept as a matter of course, little thinking of the difficulties innumerable which the printer and the 'gentle' reader encountered three centuries ago. But the very existence of a standard orthography, as a moment's reflection will show, has necessitated as its indispensable adjunct the pronouncing dictionary.

The pronouncing dictionary, therefore, is a modern production; it was hardly known before the first quarter of the eighteenth century. It is held by some scholars, notably Professor Lounsbury in his 'Standard of Pronunciation in English,' that the pronouncing dictionary was called into existence by the desire on the part of the imperfectly educated middle class to know what to say and how to say it. This desire became stronger and stronger as the members of that growing class of England's population rose by degrees into social prominence. Possessing little culture and few social advantages, and lacking confidence in their meager training, such people were not willing to exercise the right of private judgment, and consequently they sought out an authority and guide. They were eager to learn the modes of speech which obtained in the most highly cultured circles, the *jus et norma loquendi* of the nobility. It was natural therefore, since the occasion appeared to demand it, that self-appointed guides should come forward and offer to conduct the multitudes of social pariahs through the wilderness of orthoepical embarrassment into the Canaan of polite usage. Such was probably the origin of the pronouncing dictionary.

* See The Popular Science Monthly, May, 1904, 'The Question of Preference in Spelling.'

It will prove interesting to consider some of the pronunciations authorized by the early orthoepists as reflecting contemporary usage. How unlike current usage many of those early pronunciations are, the reader will see for himself. But first a word as to the orthoepists themselves.

The earliest of the eighteenth century orthoepists is Baily. His dictionary enjoyed the enviable distinction of being the first authority on English pronunciation during the first half of the eighteenth century. But Baily's supremacy was eclipsed by Johnson, whose epoch-marking dictionary appeared in 1755. Johnson claimed to record the most approved method of English orthoepy, and his prestige as a man of letters contributed speedily to establish his dictionary as the ultimate authority on English pronunciation. It is to be observed, however, that Johnson only indicated the syllable on which the accent falls. This left much to be desired as a pronouncing dictionary. So, in 1766, Buchanan, a Scotchman, gave to the world his dictionary which challenged Johnson's pre-eminence. A few years later, in 1780, to be accurate, Sheridan published his dictionary. Sheridan was an Irishman by birth, as has been said, the son of the famous British orator and dramatist, Richard Brinsley Sheridan, whose plays are so favorably known to us through Mr. Jefferson's interpretation. Sheridan's nationality was used by his competitors to prejudice the public against his dictionary and to discount it as an authority on English pronunciation. Still Sheridan enjoyed a considerable vogue.

In 1791 Walker published his dictionary. The reputation of this work, in a revised form, extended far into the last century, so we are informed by the late Mr. Ellis in his authoritative work on English pronunciation. Walker, like Sheridan, was an actor, but unlike his rival he was an Englishman by birth. He did not fail to draw attention to the advantage this circumstance would naturally give him in the popular estimation, in advertising the merits of his book. In his treatment of the principles of pronunciation, however, Walker shows a feeble grasp of his subject, and the most serious criticism upon his book is that he was unduly influenced by the spelling in ascertaining the pronunciation of a word. "In almost every part of his principles," says Mr. Ellis, an eminent authority on English pronunciation, speaking of Walker's work, "and in his remarks upon particular words throughout his dictionary, one will see the most evident marks of insufficient knowledge and of that kind of pedantic self-sufficiency which is the true growth of half-enlightened ignorance." Such drastic criticism upon the author of a dictionary which was esteemed the highest authority on English pronunciation during the first half of the last century does not invite confidence in the results of our early orthoepists. Rather it makes us feel that none of them is perhaps entitled to credit.

Probably Doctor Johnson shared this feeling when he exclaimed in the preface to his dictionary, *Quis autem custodiet ipsos custodes?*

So much for the lexicographers of the eighteenth century. Let us now consider some of the pronunciations authorized by them, which have long since been discarded. These will serve as illustrations to bring home to the mind of the reader the truth that our speech is slowly but surely and constantly changing, and that English pronunciation, unlike English spelling, has never been stereotyped in a fast, unvarying form. They will also show how indispensable an auxiliary to our crystallized, conventional spelling has the pronouncing dictionary become.

An interesting illustration is furnished by the word *asparagus*. The popular pronunciation of this word in the eighteenth century was *sparrowgrass*. This was felt by the orthoepists, however, to be a vulgar corruption of the word, and they therefore strove with concerted effort to stem the popular tide and to make the pronunciation conform to abstract propriety as indicated by the spelling. Walker, in commenting upon the pronunciation of the word, remarks, as if apologizing for the theoretically correct form which he recommends, that 'the corruption of the word into *sparrow-grass* is so general that asparagus has an air of stiffness and pedantry.' Another word with a no less interesting history is *cucumber*. This word used to be generally pronounced *cowcumber*. The popular pronunciation of this word as well as of *asparagus*, once so universal, has survived even up to the present in the lingo of the illiterate whites of New England and in the Negro dialect. This vulgar pronunciation which was a thorn in the flesh to the eighteenth century lexicographers, it is instructive to note in passing, was not the result of mere caprice, but was warranted by an old variant spelling of the word. This historic spelling, long since discarded altogether by the users of English, was formerly very prevalent and in good literary usage. Hence little wonder that the vulgar pronunciation for a long time contested the supremacy with the mode of utterance now universally accepted. Even so high an authority as Mr. Pepys refers in his 'Diary' to a certain man as 'dead of eating cowcumbers.' It was not till wellnigh the middle of the last century that the orthoepists Knowles and Smart ventured to denounce *cowcumber* along with *sparrow-grass* as vulgar and therefore tabooed in polite circles.

It is a well-established fact in the history of English pronunciation that in the seventeenth century and far into the following century such words as *spoil, toil, boil,* and so on, were pronounced, even in best usage, precisely as they are uttered to-day in the Negro dialect and by the illiterate whites among us, that is, just as if they were written 'spile,' 'tile' and 'bile.' This is conclusively proved by the

rhymes of Dryden and Pope. It is further evident from the rhymes of the poets of the latter half of the eighteenth century that this archaic pronunciation persisted almost down to the beginning of the last century. This pronunciation was regarded by the orthoepists as antiquated and vulgar, and they did not fail to denounce it in strong terms, warning against its use. In 1773 Kenrick records with mingled regret and disgust that it would appear affected to pronounce such words as *boil, join* and many others otherwise than as 'bile' and 'jine.' But toward the close of the eighteenth century the present pronunciation began to prevail and 'the banished diphthong,' as Nares records with triumphant delight, 'seemed at length to be upon its return.' This same orthoepist informs us, and we may well believe him, that it was the authority of the poets, who had pilloried the offensive pronunciation in their verse, that retarded the progress of the received sound of the diphthong which finally triumphed.

The early lexicographers were divided on the pronunciation of *vase.* Indeed, two centuries have not sufficed to unite their successors in perfect harmony on this question. The word to-day vacillates between four received pronunciations. The great unwashed pronounce *vase* to rhyme with *base* and *case.* Some pronounce the word as if written 'vaz' with 'the broad a.' Others, associating it with its French equivalent, pronounce the word 'vauze.' Others still pronounce it so as to rhyme with *amaze* and *gaze.* Of these four pronunciations the first is the most prevalent to-day, as it also was two centuries ago. According to the Century Dictionary, the word was introduced into English during the latter half of the seventeenth century, and after the analogy of words of its class, it would naturally be pronounced so as to rhyme with *case* and *base.* But the recency of the word and its familiar association with art have given rise to the attempt to make it conform to the analogy of the French pronunciation and sound it as if written 'vauze.' The early occasional spelling of the word as *vause* doubtless contributed somewhat to the extension of this latter pronunciation. This French pronunciation, says the Century, is now affected by many. It is worth while to remark, however, that while the Century recognizes the French pronunciation, it still gives the preference to the old historic pronunciation, viz., that rhyming with *case* and *base.*

Now, in the eighteenth century some of the orthoepists favored one pronunciation and some another. Sheridan, Scott, Kenrick, Perry and Buchanan declared for the pronunciation rhyming with *case* and *base.* On the other hand, Smith, Johnston and Walker expressed themselves in favor of 'vaze.' Walker says that he has uniformly heard it so pronounced, but adds the significant remark that the word is pronounced according to the French fashion 'sometimes by people of re-

finement; but this, being too refined for the general ear, is now but seldom heard.' This French pronunciation, however strange the comment may appear to us in view of his wide acquaintance with English usage, the late Mr. A. J. Ellis averred was the most familiar to him. So the struggle between the several pronunciations of *vase* continues still, and no one can say which will ultimately prevail.

Another interesting illustration of vacillation of usage two centuries ago is furnished in the pronunciation of *either* and *neither.* Like the word *vase,* these words show incidentally how long a time two pronunciations of the same word may linger in good usage before either supplants the other. There is to-day probably as much variation in the pronunciation of *either* and *neither* as there was a century and a half ago. Early in the eighteenth century the *i* sound was conceded by some of the orthoepists as permissible in these words. Two authorities, Buchanan and Johnston, declared for the new pronunciation, that is, 'ither' and 'nither.' But since they were both Scotchmen, their authority was discounted. On the other hand, Sheridan and Walker recommended the *e* sound and used their influence to bespeak for it general endorsement. They recognized the *i* sound, to be sure, but only on sufferance. From that day to the present the battle has waged more or less fiercely between the advocates of these respective pronunciations of *either* and *neither.* Which will ultimately prevail, it is impossible to determine. It may be said, however, that analogy and history are on the side of the *e* sound. Yet the *i* sound appears to be encroaching at present on the former pronunciation. There is still another pronunciation of these words which we now rarely hear. I refer to the old dialectical pronunciation as 'ather' and 'nather.' This pronunciation was current in Doctor Johnson's time, though it probably did not enjoy the sanction of good usage. On being asked one day whether he regarded 'ither,' or 'ether' as the proper pronunciation of *either,* the old Doctor is said to have blurted out in his characteristic crabbed manner, 'Nather, Sir!' This pronunciation survives now only as an Irishism.

Another class of former pronunciations surviving now as an Irishism, or at best as a provincialism merely, is exemplified by such words as *nature, creature* and *picture.* In Dryden's and Pope's time these words were pronounced 'nater,' 'crater' and 'picter.' These pronunciations are preserved still in the Yankee dialect, as shown in Lowell's inimitable Biglow Papers, and of course they are frequently heard on Irish lips. But they long ago dropped out of the speech of polite society. There is one notable exception found in the word figure. The variant pronunciation of this word as 'figer' survives in standard English as a heritage from the seventeenth century.

Quite as instructive an illustration of survivals in pronunciation is

furnished by the British pronunciation of *clerk* and *Derby*. The English, as is well known, pronounce these words as if written 'clark' and 'Darby.' They used to pronounce *clergy* with the same vowel sound, and many other words besides. But it is a significant sign of the approaching change in British usage in respect to these words that a recent British dictionary, the New Historical, in commenting on *clerk* admits that the American pronunciation of this word has become somewhat frequent of late in London and its neighborhood. (Are we to look upon this as a result of the much-discussed American invasion?) But our British cousins are still wedded to their Derby (Darby) and show no sign of abandoning either the old pronunciation or the custom. Even we Americans cling tenaciously to *serjeant* and show but little inclination to make that conform speedily to the analogy of other words of its class and to pronounce it in accordance with the spelling. But, no doubt, this word, also, in the course of time, will yield to the pressure of analogy, and our time-honored *serjeant,* with the flight of years, is destined to be classed among those pronunciations that have lost caste. The early orthoepists uniformly pronounced this entire class of words as our British cousins pronounce them at the present time, that is, as if they were written 'clark,' 'sarjeant' and so on. Indeed, it is the spelling that has been the main factor in effecting the change in the pronunciation of these words. There is a strong tendency in English to pronounce a word as it is written, and this tendency has been asserting itself with ever increasing force since English spelling has been crystallized and thereby rendered less subject to preference or caprice.

A constantly recurring question, which never ceased to vex the spirit of the early orthoepists, was, where to place the accent in the case of *contemplate, demonstrate, illustrate* and similar words of classical origin. The question at issue here is whether the stress shall fall upon the antepenultimate or the penultimate. Even with all the accumulated knowledge of the centuries we are no nearer a solution of this perplexing question than were the Elizabethans. Shakespeare could say indifferently cónfiscate or confíscate, démonstrate or demónstrate. Here the battle has been waged between the scholars, on the one hand, who insist upon strict propriety, and the uninitiated, on the other, who follow the line of least resistance and by intuition place the accent upon the initial syllable. As is evident at a glance, these words come to us from the classics. The scholars therefore, somewhat pedantically, insist upon retaining the stress on the syllable which bore it in the original Latin or Greek. *Per contra,* the common people, who know 'little Latin and less Greek' and care not a fig for the original accent, instinctively throw the stress upon the first syllable, in keeping with their feeling for their mother tongue. This feeling

for the language, which the Germans call 'Sprachgefühl,' is, after all, a safer guide than the rules laid down by the pedants. Candor compels us to admit that the popular tendency is more in harmony with the genius of our vernacular. But the scholars have made a brave fight for what we may denominate abstract propriety, and the result, thus far, is a drawn battle. Each side has scored some points, and each side has had to make some concessions. Thus *balcony, academy, decorous* and *metamorphosis,* to cite a few concrete examples, have finally triumphed over the earlier pedantic pronunciations, which required the accent on the penult of these words. *Horizon,* on the other hand, stands as a monument of a concession to the learned, since this word in Elizabethan times had the stress on the initial syllable, as had also the name of the month July. Popular usage in favor of the received pronunciation of *auditor, senator, victory, orator* and many similar words has achieved a decided triumph over the early orthoepists, who, it was very obvious, were fighting a losing battle in their efforts to retain the classical accent.

It follows that pronunciation is the resultant product of several forces which are silently but constantly acting upon the living language. There are, to be sure, various methods of pronunciation, but the standard is that sanctioned by the most cultivated circles of society. Now, it is the function of the pronouncing dictionary, and its sole reason for existence, to determine and record the usage of the most cultured classes. But here is where the rub comes. This is the stumbling-block in the way of the lexicographers. It may seem, upon first blush, that the task of the orthoepist is easy enough. But not so in actual practice. Countless and insuperable difficulties soon begin to loom up a little ahead in the path of the intending orthoepist, and he finds, to his regret and his occasional disgust, that the way he has marked out for himself is not strewn with roses. It is an arduous undertaking which holds out but meager hope of successful accomplishment, to make an accurate record of the pronunciation received in any large class of society. The labor and trouble are multiplied many times when an attempt is made to determine the best orthoepical usage in a democracy. There is really no absolute standard of pronunciation in English and there can not be, from the very nature of the case, as Professor Lounsbury has clearly demonstrated in his recent luminous book on this subject.

Yet it is unquestionably true that the pronouncing dictionary is constantly making for uniformity of pronunciation. There is far less difference in English orthoepy at the beginning of the twentieth century, even despite the present diversity of good usage, than there was at the beginning of the eighteenth century. A glance at the history usage. If we may trust Professor Lounsbury, an eminent authority

of English pronunciation will readily convince the reader of this fact. This result is the direct outgrowth of the increased facilities for intercourse between communities, and of the gradual diffusion of education which the last two centuries have witnessed. With the spread of education there go along those habits of speech which are generally recognized to be in accord with best usage and which therefore have most to commend them to popular favor. But till men cease to exercise the right of choice in the mode of utterance, till men prefer, for the sake of uniformity, to say exclusively hóstĭle and not hostīle, sérvĭle and not servīle, 'rise' and not 'rice,' to mention an example of variant usage, so long will there probably be a diversity of pronunciation and the consequent need for the pronouncing dictionary. This consummation so devoutly to be wished we may expect at the Greek Kalends. We may rest assured, therefore, that the pronouncing dictionary is here to stay.

Every man has his preference as to his pronouncing dictionary, which he regards with more or less confidence and, may be, reverence, as his final authority. To this he resorts in all orthoepical questions, for final solution. This, of course, is a legitimate function of the pronouncing dictionary. The fact is, the vocabulary of the average educated man is so extremely limited and the vocabulary of the language so extremely copious that there are thousands of words of a technical character which even the most accomplished scholars have never once heard uttered. The average educated man who knows that English spelling is a very untrustworthy guide to pronunciation is perforce driven to consult his Webster, or his Worcester, or his Standard, or mayhap his Century. Only then can he pronounce an unfamiliar English word with any assurance of propriety.

Notwithstanding the fact that every educated man has his favorite dictionary, it is probably true that no man's pronunciation is in entire accord with the dictionary he habitually follows. The late Mr. Ellis gave a suggestive test which I believe has never been successfully challenged. "I do not remember," said he, "ever meeting with a person of general education, or even literary habits, who could read off, without hesitation, the whole of such a list of words as: bourgeois, demy, actinism, velleity, batman, beaufin, brevier, rowlock, fusil, flugleman, vase, tassel, buoy, oboe, archimandrite, etc., and give them in each case the same pronunciation as is assigned in any given pronouncing dictionary now in use." Let the reader try these test words and see whether he pronounces this short list according to any received authority in use at the present day.

It may not prove an altogether unprofitable inquiry how our pronouncing dictionaries are made. Such an inquiry, if pursued, may teach us somewhat of the methods of the orthoepists to ascertain good

on English, the method formerly adopted was very much after this fashion: The lexicographer studies in his own library the pronouncing dictionary of everybody who has taken the pains to compile one, whether he be an Englishman, an Irishman, a Scotchman, or an American. He compares these several dictionaries and records their variations. From these he selects those pronunciations which, for any special reason, commend themselves to his individual taste or judgment. These are usually such pronunciations as he is accustomed to hear or himself to use. These are published with the stamp of the lexicographer's authority and approval, and the dictionary is sent out into the world as so-and-so's record of the most approved usage.

This was doubtless the way pronouncing dictionaries used to be compiled. But we may believe that this method is not the course ordinarily followed by the authors of our best modern dictionaries. If our best standard dictionaries to-day were made in this fashion, their authority would richly deserve to be heavily discounted for such carelessness of method. But greater efforts are made by the most recent orthoepists, we may believe, to determine the accepted usage in polite society. Yet, after all, the personal equation enters as an important factor into the compilation of every pronouncing dictionary. The author or authors who compile the dictionary naturally follow their own preferences and prejudices in the matter of pronunciation; and their results, even at best, repose on very restricted and imperfect observation. An orthoepist ought not to be cocksure and dogmatic. Indeed, the proper attitude of the author of a dictionary is that of the late Mr. Ellis. It was quite natural that a man of his superior scholarship and rare orthoepical attainments should have been frequently asked as to the proper pronunciation of a particular word.

"It has not unfrequently happened," observes Mr. Ellis in his monumental work on 'Early English Pronunciation,' in reference to his practice, when appealed to as an authority, "It has not unfrequently happened that the present writer has been appealed to respecting the pronunciation of a word. He generally replies that he is accustomed to pronounce it in such or such a way, and has often to add that he has heard others pronounce it differently, but that he has no means of deciding which pronunciation ought to be adopted, or even of saying which is the more customary."

This attitude will, no doubt, commend itself to the favor of the reflecting and judicious man much more forcibly than that spirit of assumed infallibility which is a sure sign, in an orthoepist, of insufficient knowledge and lack of preparation for his work. The business of a lexicographer is to record what good usage authorizes, not to tell us what we shall not use. The orthoepist who goes farther, and dogmatically asserts that a given pronunciation is correct and another

incorrect, transcends the legitimate bounds of his province. Moreover, he arouses suspicion in the minds of the thoughtful as to his trustworthiness as a guide in matters of pronunciation. For no orthoepist records all the pronunciations sanctioned by good usage, and no one therefore can affirm positively that a given pronunciation of a word may not be warranted by reputable usage in some quarter. Even so high an authority and careful an observer as Ellis lapsed into error in his comment upon the pronunciation of *trait*, claiming that the silent final *t* was an unfailing shibboleth of British practice. As a matter of fact, the pronunciation of the final letter of *trait,* as Professor Lounsbury has clearly shown, had been recognized by English orthoepists as allowable for more than a century. It is manifest that one can not afford to be very positive in English orthoepy: if he is, he will be compelled either to retract or to qualify some of his sweeping statements.

The pronouncing dictionary is, as a general rule, a good guide to standard usage, though it can not be relied upon implicitly. When the orthoepists are all agreed upon a particular pronunciation, one ought to be very chary of using one's customary or pet pronunciation that differs. The chances are that it is not in good repute. But when, on the contrary, the orthoepists themselves differ, one may reasonably infer that no statement of any one of them about the proper pronunciation of a word, however positive it may be, ought to be recognized as a binding authority. For no pronouncing dictionary is an absolutely final authority. Nor can it ever justly claim to be, since the pronouncing dictionary purports to record only such pronunciations as are sanctioned by good usage, and good usage ever varies with the living speech, which, like all living things, is always slowly changing from century to century. The change is sometimes so gradual that hardly the lapse of a century will reveal it. Again, for one reason or another, it is so rapid in development that even a generation suffices to record it.

THE BERMUDA ISLANDS AND THE BERMUDA BIOLOGICAL STATION FOR RESEARCH. II.

By Professor EDWARD L. MARK,
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BEFORE speaking about the life in the seas I wish to say a few words about the Bermuda Marine Laboratory. Not very long after my conversations with President Eliot, and when I was considering ways and means of providing an opportunity for students to work at Bermuda, I had the good fortune to make the acquaintance of Professor Bristol, and hear from him for the first time a glowing account of his experiences of several years, and his plans and hopes regarding a somewhat similar undertaking. Our aims had so much in common that cooperation seemed desirable to both of us, and we at length agreed to undertake, with the aid of the Bermuda Natural History Society, to equip and manage a provisional laboratory, which might serve till such time as the colonial government should be able to put at the disposal of biologists a permanent station. Chiefly through the enthusiastic interest of Dr. Bristol, in cooperation with the Bermuda Natural History Society, the colonial government had been led to entertain the idea of establishing a public aquarium for the enlightenment and amusement of people resident in the islands as well as the tourists, and in connection with it a marine laboratory for biological investigations. A joint committee of the Legislative Council and the House of Assembly, consisting of Sir S. Brownlow Gray, chief justice, Hon. Eyre Hutson, colonial secretary, and assemblymen J. H. Trimingham, Nathaniel Vesey and A. Gosling, was appointed to consider the advisability of establishing such a station, and in due time reported favorably on the undertaking. The governor, Lieut.-General Geary, at the suggestion of the committee, entered into correspondence with many institutions and individuals in both Europe and America, with a view to ascertaining their opinions as to the desirability of establishing such a station and the possibility of their cooperation. The replies were all favorable, and a certain amount of support was promised. Early in 1903 Professor Bristol and I were invited by the Natural History Society to visit Bermuda for the purpose of looking into the conditions and giving advice with regard to the general plan and certain matters of detail. This we did toward the end of April. Upon our return, and after the money necessary for the undertaking had been secured, we issued to biologists in the name of

the Bermuda Natural History Society and the universities which we represented an invitation to share for six weeks in the privileges of a temporary biological station at the Flatts, Bermuda. The generosity of the Natural History Society and the liberality of our friends allowed us to provide ample means for collecting and all the requisites for laboratory work, except that we had no running water in the laboratory. The building, however, was only a short distance from the sea, so that this deficiency was not very serious.

Through the favorable terms for transportation secured from the Quebec Steamship Co., and for board and lodging at the Hotel 'Frascati,' it was possible to make the cost of staying six weeks at the station, together with transportation from New York and back, only

FIG. 13. VIEW OF FLATTS VILLAGE FROM WINDOW OF HOTEL FRASCATI. Photograph by A. M. Miller.

one hundred dollars. Thirty-seven persons availed themselves of this opportunity, and of these thirty-three were engaged in the study of zoology or botany, four being companions of one or another of those who were working in the laboratory. Of these thirty-seven persons about a dozen sailed from New York on June 20, the remainder two weeks later. Arriving in Hamilton, the party was met on board the steamer and welcomed by Archdeacon Tucker, president of the Bermuda Natural History Society; U. S. Consul, W. Maxwell Greene, vice-president; F. Goodwin Gosling, honorary secretary, and other members of the society. A carriage ride of four miles over Mt. Langton and along the north road—from which one gets magnificent views of the great north lagoon and its ever-changing appearance—

brought the party to the Flatts and the hotel. The Flatts village (Fig. 13) centers at the cross-roads near the bridge which spans the narrow passage from the Inlet into Harrington Sound. It contains the hotel, the post office, a half-dozen shops, and one or two scores of dwellings, which range in size and attractiveness from 'Palmetto Grove,' the home of Archdeacon Tucker, to the twenty-foot cottage of the unambitious colored family. On nearing the Flatts the north road runs along the hillside that rises to the south of the Inlet, gradually descending to sea level, at the corners, where it meets the middle road. The cottages are scattered over this hillside, which looks out on Harrington

FIG. 14. VIEW OF HOTEL 'FRASCATI,' LOOKING OUT THROUGH THE INLET. Photograph by Albert Mann.

Sound and affords at many spots beautiful views of that land-locked sea and the wooded heights beyond. The hotel (Fig. 14) is located on a low projection of land that makes out into the Inlet from its south shore and commands on one side a view of the sea (Fig. 15), on the other a view into Harrington Sound. It consists of half a dozen buildings; two of stone (one built as a residence many years ago) placed gable to gable and facing the water; a much newer wooden structure, which, with its broad piazza, projects out over the clear waters of the Inlet; the kitchens and a storehouse behind the older buildings; and, lastly, a new stone building some forty feet square located back of the wooden

one, between it and the public road. This building we rented for a laboratory (Fig. 16); it had been divided up by light partitions into several rooms, and proved to be fairly well adapted to our needs. The laboratories were furnished with substantial work tables, having ebonized tops and banks of drawers. A library of specially selected books and pamphlets from the libraries of the Museum of Comparative Zoology, the Boston Society of Natural History, and the writer, several hundred in number, was arranged in the largest workroom. An ample supply of glassware, reagents and preservatives, dissecting lenses, microtomes, paraffin imbedding appliances and all the other usual equipment of a zoological laboratory were provided, as well as the necessary appliances for collecting, such as dredges, nets, seines, tubs,

FIG. 15. VIEW OF 'WISTOWE' AND THE INLET FROM THE PIAZZA OF HOTEL 'FRASCATI.'

buckets, sieves, water glasses, et cetera, so that few wants were felt in this direction by any of the party. The number of students was, however, so large that the laboratory building was inadequate for the accommodation of all. When the second party arrived, therefore, a large ground-floor room in one of the stone buildings of the hotel was fitted up with portable tables for those who had less need of appliances for microscopic work.

Very satisfactory means of transportation to collecting grounds, both by land and by water, were provided. For places not readily accessible by boats, wagonettes and carriages were furnished, and those who collected land plants made much use of them. Several persons had brought with them their bicycles and thus were less dependent on

the organized parties. Regular excursions were arranged for nearly every day, except Sundays; frequently two in a day, and sometimes two by sea and one by land. As far as practicable shore collecting and coral 'nipping' on the reefs were planned for the low-tide hours of the day and dredging for other times.

One of the places most frequently visited by land conveyance was Hungry Bay, on the south shore nearly opposite Hamilton. The entrance to the bay is narrow and rocky, yet a great variety of animals are blown in by the southerly winds, and the place has thus become a rich collecting ground. The loose and porous rocks just inside the

Fig. 16. The Laboratory, Western Face. Photograph by C. L. Bristol.

entrance on either shore afford hiding places for great numbers of worms and other invertebrates. Upon turning over these rocks the bottom seems alive with creatures of many kinds. Only half the booty is seen, however, unless the rocks are broken into fragments. Thus are set free boring mollusks, annelids and many other forms that find protection, or a lair, in the holes and tortuous passages of this porous, honeycombed limestone.

In many places the floor of the shallower parts of the bay is covered by a large tubularian hydroid, in others, where the current

is stronger, by great yellowish or greenish patches of colonial actinians (*Palythoa*) belonging to the Zoanthidae (Fig. 17). The upper end of this bay is a swamp of mangroves (compare Fig. 18), on the branches of which numbers of tree crabs (*Goniopsis cruentatus*) clamber about. To catch these creatures requires some skill, two persons usually succeeding better than one, for the crab, when too closely pursued, quickly drops to the ground, even from a height of ten or fifteen feet, and escapes into a burrow, unless a net is dexterously interposed during his descent. Along the edges of the tidal stream near the head of the bay are found in great numbers prawns that are so transparent as to escape observation until they move; they dart about with such swiftness that it is difficult to take them in the net.

When one cautiously approaches the edge of the cliffs that flank the entrance to the bay and looks down on the hard, wave-beaten rocks he sees large numbers of crabs that take alarm at the least motion and scurry away to crevices, or scramble down into fairly deep water, where with their sharp claws they are able to cling to the rough rocks and make almost as good progress as in the air. On the platforms and in the niches of the rock between tide marks are congregated hundreds of chitons (*Chiton marmoreus*), whose shells give proof of the action of the waves, which are almost constantly dashing against them at high water.

In view of the possibility of the establishment of a permanent station, it seemed desirable to keep records of the places where various animals and plants were found. To this end each person was provided with a note book, and to prevent duplication of locality numbers, certain locality numbers were assigned with each book. Whenever a party of individuals made collections together in a circumscribed area, as in dredging, or in shore collecting at particular spots, the same locality number was used by all. To enable future workers to find the precise localities mentioned, these places were designated by latitude and longitude. Fortunately for this plan there had been recently published an Ordinance-Survey map of the Bermudas on a scale of 880 feet to the inch, so that by ruling one of these maps with rectangles ten seconds square it was possible to indicate on the map the position of any locality to within a very few feet.

A card catalogue embracing the names of all the animals and plants arranged systematically will ultimately show, not only what organisms, both living and fossil, are to be met with in the islands and adjacent waters, but also the precise localities at which they have been found, and the conditions under which they live. To this will be added as rapidly as possible the periods of ovulation, etc., so that one may not waste time in searching in the wrong place or at the wrong time of year for the material one needs.

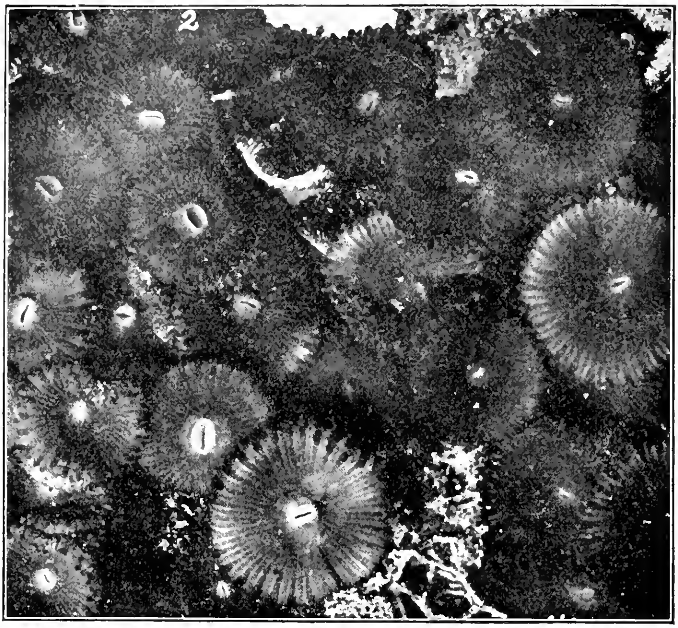


FIG. 17. *Palythoa grandiflora.* A GROUP OF LIVING ANIMALS Natural Size.

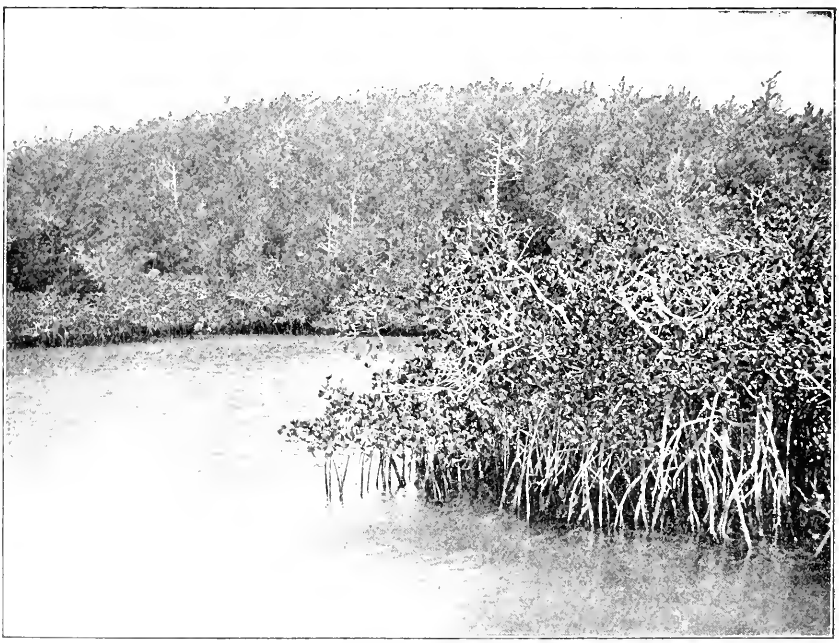


FIG. 18. WALSINGHAM BAY. MANGROVES AND, IN THE BACKGROUND, CEDARS. Photograph by W. C. Van Name.

* Figures 17, 19–23 and 27 are from photographs by A. Hyatt Verrill.

In the immediate vicinity of the laboratory—in the Inlet and in Harrington Sound—are found an abundant supply of many interesting animals. From the stone pier at the hotel are to be seen great numbers of brightly colored fishes: the yellow-banded sergeant majors (*Abudefduf saxatilis*), sea squirrels (*Holocentrus ascensionis*), so called on account of the bigness of their eyes, angel fishes (*Angelichthys ciliaris*), four eyes (*Chætodon bimaculatus*) and many others. The large eye-spots of the four-eyes at the tail end of the body evidently afford protection by misleading their enemies into the belief that they will attempt to escape in a direction opposite that in which they actually swim. Schools of blue fry and other small fishes pursued by their enemies make a flash in the sunlight as they leap from the water and a sound like the patter of rain as they descend. Small shoals of white grunt (*Bathystoma*), that so closely resemble the sandy bottom as to be almost invisible, are slowly patrolling along the beach and often attract one's attention only when their presence causes a commotion among their prospective victims.

The water is so clear that the bottom at a depth of fifteen or twenty feet is seen as distinctly as it would be beneath as many inches of our northern waters. Along the sandy stretches of the inlet, where the current is not too strong, are numerous dark sea-urchins (*Toxopneustes variegatus*), which have the interesting habit of covering themselves with empty shells, seaweeds or any loose available fragments. Just what sort of protection these screens afford is not quite apparent. To the observer looking from above they are scarcely less conspicuous than when unadorned. Their specific form and characteristic color, it is true, are masked, and possibly this is enough to subserve some useful purpose. By digging a few inches deep in the sand at the right spot one brings up another echinoid, the sand-dollar (*Mellita sexforis*). Scattered over the bottom are the apparently motionless but conspicuous sea-cucumbers, which the natives call sea-puddings—the *Stichopus diaboli* and *S. xanthomela* of Heilprin. These often attain the length of a foot or more and leave behind to mark the track of their slow progress a cord or ridge of sand that has been deprived of its nutritive material in passing through their intestinal tract. These are abundant on many sandy bottoms; other holothurians are less widely distributed. In the shallow parts of the Inlet, which are laid bare at low tide, are the burrows of many annelids and other worms. Where the channel is rocky and the water moves with greater velocity the bottom is often gorgeously painted with patches of bright-colored corallines and encrusting sponges. Opposite the hotel an artificial channel cut through the narrow neck of land that separates the Inlet from Harrington Sound is of this nature and affords a rich collecting ground for many invertebrates. With a row

boat and a good water-glass one may study with delight the shores of Harrington Sound and its numerous coves and get beautiful views of the delicate shade-corals (*Agaricia fragilis*, Fig. 19), the many kinds of sea anemones (Figs. 20, 21, 22) and the sponges, which abound there. Collecting is easy and the variety of life great. Occasionally the long 'whips' of the Bermuda lobster (*Panulirus argus*) are seen projecting out of some cervice in the rock, as he lies in wait for his prey. If less palatable than our American lobster, the Bermudian has a more graceful form and a much handsomer livery (Fig. 23).

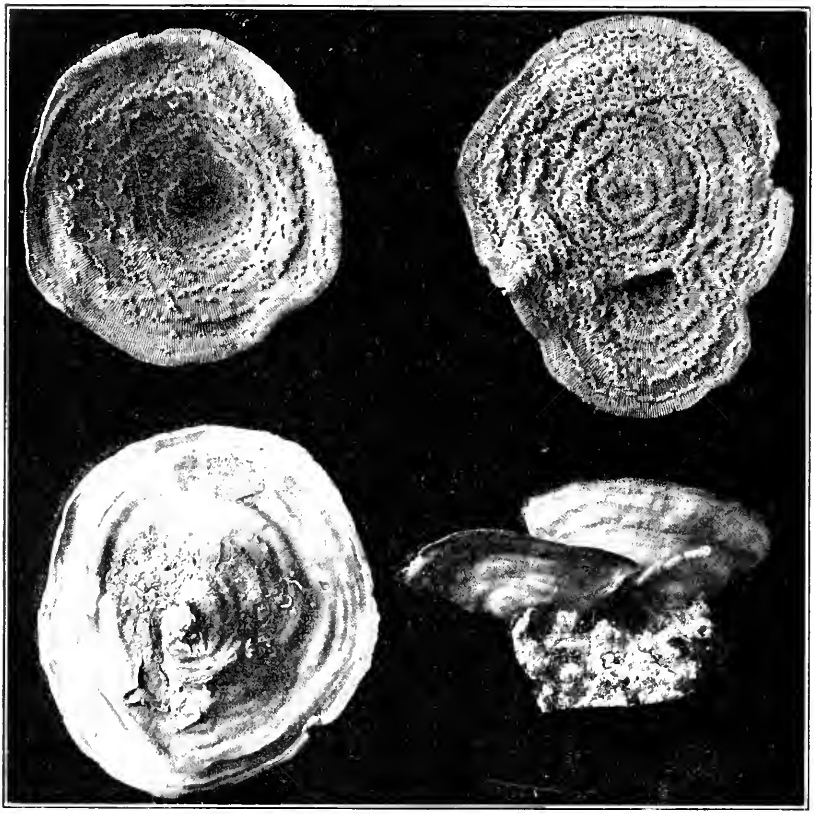


FIG. 19. SKELETONS OF SHADE CORALS.

In addition to a thirty-foot sail boat with its glass-bottomed fish well, such as the native fishermen use, the station was furnished in the summer of 1903 with a steam launch (Fig. 24) some 35 feet long, the *Minnow*. For three fourths of her length she had a light wooden deck and side curtains, which could be lowered to keep out sun, rain or spray. Her pilot house was low, but roomy, and served as a forward cabin as well as wheel house. In this launch almost daily

excursions were made to various parts of the archipelago, according as the conditions of wind and tide favored this or that locality. For all purposes except that of dredging she was well suited to our needs, for, being of light draught, she could be used about the shoals and flats with safety and ease.

I recall with pleasure not only my own fascination, but also the

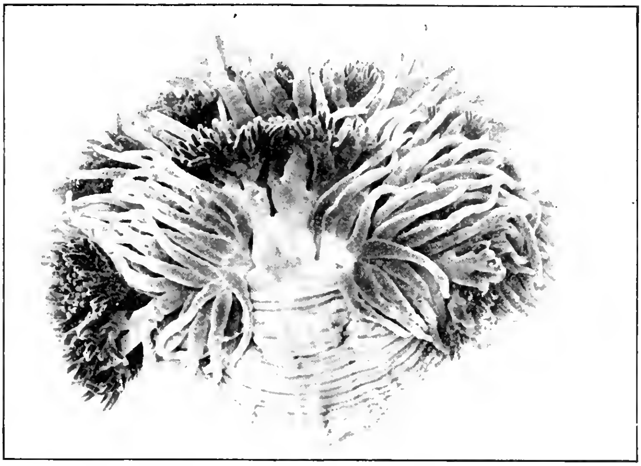


FIG. 20. ACTINIAN (*Lebrunia Danæ*). × ½.

expressions of delight which involuntarily came from the lips of all who, with water-glass in hand, peered down into the fairy-like gardens of the sea, as we slowly drifted with the tide or lay at anchor in the midst of one of the great coral patches that flourish over extensive

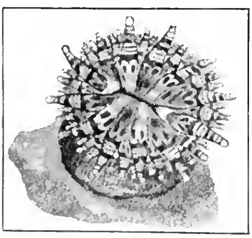


FIG. 21. *Anemonia elegans*, VERRILL. × 1¼.

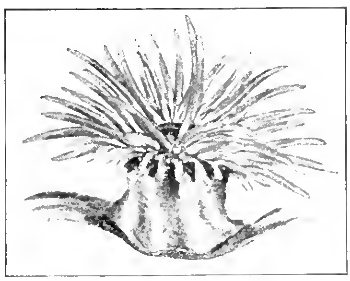


FIG. 22. *Phillia rufa* VERRILL. × ½.

areas of the north lagoon. I confess the pleasure was so great that the spirit of the collector was suppressed for the time being; it seemed sacrilege to touch with violent hands a picture that showed such harmony of form and color—the waving plumes, the graceful branches

of the gorgonias; sea fans in purple splendor; coral heads of gold and green; great splotches of colored sponges encrusting the rocks; the soft seaweeds; here and there deep channels with nothing but the clear water and the white sand beneath it; and in and out among this maze of growing things, the graceful, noiseless fishes in such array of colors as is scarcely credible, much less describable. I believe it may be truly said that one who has never seen such a tropical sea-garden

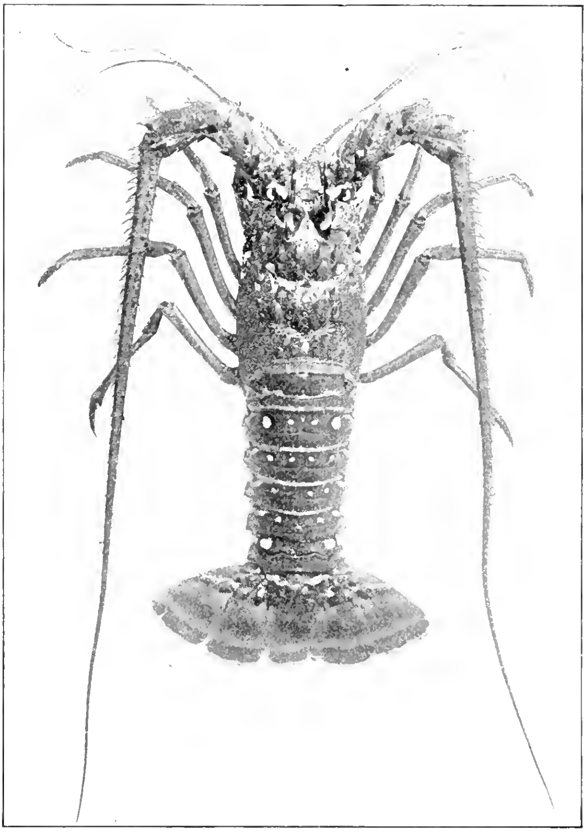


FIG. 23. BERMUDA LOBSTER. About ¼ natural size.

can not have the remotest idea of its charm. There was only one consideration that could reconcile me to the wanton work of collecting these beautiful things and robbing them of all their native charm; that was the fact that, work as diligently as we might, we could not deface one in a thousand of these fascinating spots. I think there is no other single experience I would willingly exchange for this; and yet I recall one other, of a somewhat different nature, that made a

strong impression on me. As three of us were out one afternoon off the south shore beyond the reefs fishing in about sixty fathoms, there came floating past with the tide a school of jelly fishes, the common *Aurelia*. I had before seen *Aurelia* almost cover the surface of the sea, but never before had I been able to look down, as then, and see them in the depths of the sea. They were seemingly without end, a vast procession, smaller and smaller the deeper one gazed, until they seemed mere specks, such was the clearness of the water.

For use in dredging a much larger steamer (Fig. 25), the *Intrepid*, was for a part of the time at our command in place of the *Minnow*. This steamer was provided with a boom in front of the pilot house, which much facilitated dredging operations, and the forward deck was

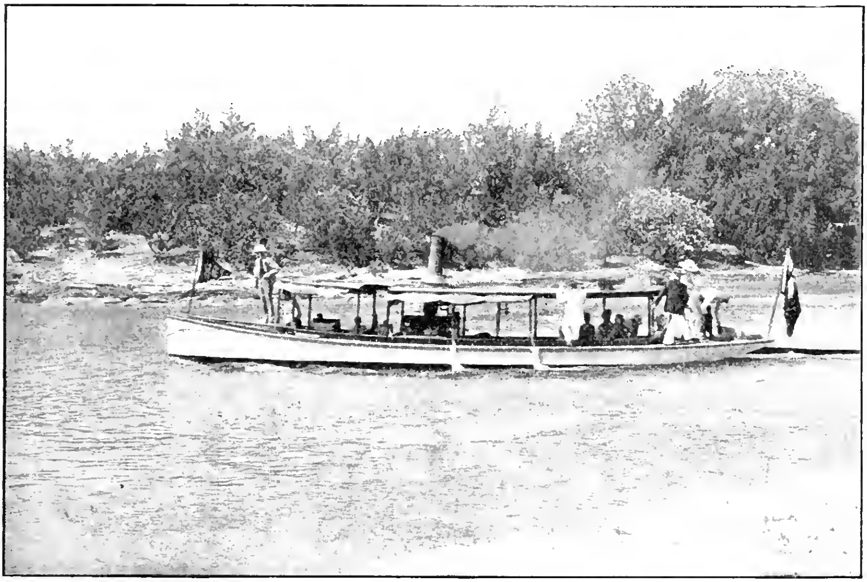


Fig. 24. The 'Minnow' Starting on an Excursion. Photograph by Albert Mann.

a convenient place for inspecting the dredgings, assorting tows, etc. This was the steamer that had been employed by Mr. Agassiz during his explorations in 1894. With her we made, besides other excursions, several trips to North Rocks (Fig. 26)—three sole survivors of a land mass that doubtless extended in previous times along the northern border of the lagoon, as the present land area now does along its southern rim. It is only on the calmest days and at lowest tide that one may safely land on the plateau from which these three pinnacles, called North Rocks, arise. The steamer can approach within a half or a quarter of a mile and then must anchor, while in rowboats the collectors

make their way to this sea-washed platform. On the sea face the rock, which is an æolian limestone, is slightly raised above the general level of the floor, and is overgrown with nullipores and other corallines,

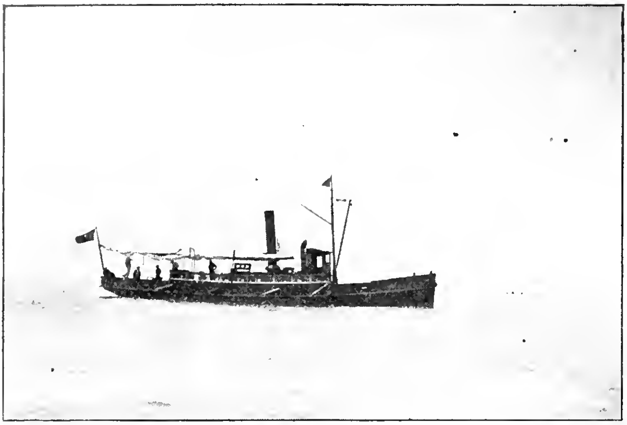


FIG. 25. THE 'INTREPID.' From a photograph by L. J. Cole.

as well as non-calcareous algæ; and here serpulas, millepores and porites abound. Even at low tide this rocky platform is barely above water, and it is so honeycombed and porous that its surface is very

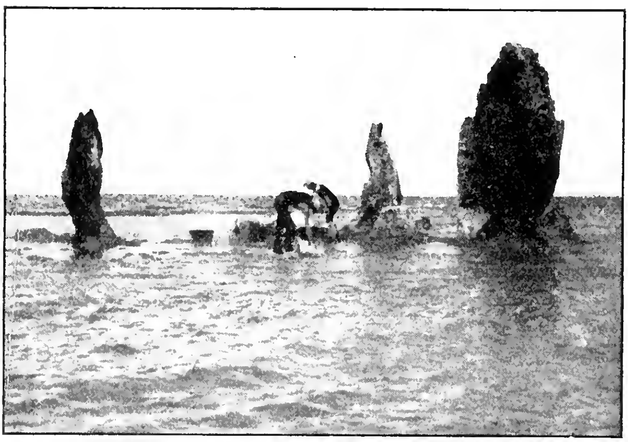


FIG. 26. NORTH ROCKS. From a photograph by Phelps Gage.

irregular. The flatter portions are covered here and there with patches of the curious Zoanthidæ. There are innumerable pools and channels all showing the greatest variety of color in the plant and animal life that clothes their sides and bottoms. Here in the pools and passages,

is a greater wealth and variety of life than can be found in an equal area elsewhere in all the Bermuda archipelago. Located on the very edge of the outer reef, where breakers are always running, save in perfectly calm weather, the conditions seem to be especially favorable for many of the marine organisms. Numerous small and brilliantly colored fishes dart about in the pools, and escape into the crevices of the rock as one attempts to scoop them up. The great black sea-urchin (*Diadema setosum*) bristling with slender spines is firmly ensconced in niches in the rocky floor and usually defies all attempts at removal. But by breaking away the rim of protecting rock this urchin may sometimes be dislodged. Unless great care is used, however, his spines, which are like needles, will penetrate the flesh, where they are sure to break off and become a source of great irritation if not promptly removed; but they are so brittle that removal is not an easy matter. Crabs both great and small are everywhere, and the little hermits with their molluscan shelters of various kinds and sizes make a grotesque appearance as they scuttle away to cover.

One of the most novel sights that I saw in these tropical seas was viewed through a water-glass near North Rocks. A school of small fishes (*Atherina*) swimming in a nearly spherical mass ten or fifteen feet in diameter, seemed to be slowly revolving through the water as its individuals swam round and round in an almost solid mass. It was not at first apparent how the mass preserved such a constant form, but at length it was seen that a few individuals of another and larger species of fish were acting the part of the shepherd dog, and that the smaller fishes were actually being herded—a flock of submarine sheep. Nor do the herding fishes prey upon their flocks. The explanation is interesting. Three kinds of fishes are involved in this association. The herders accompany and 'round up' the smaller fishes, so that other kinds of fish which are wont to prey upon them may, as they approach with murderous intent, fall victims to the herders.

Picturesque Castle Island, which still contains ruins of early fortifications,—some of them possibly dating from the early part of the seventeenth century,—once guarded the entrance from the sea through the channel of Castle Roads. From the floor of this channel the dredge brings up many interesting animals: the great conchs (*Strombus gigas*), the shells of which are still prized by tourists, living Foraminifera of several kinds, and, best of all, the Caribbean *Amphioxus*. This species was dredged in considerable numbers at various places during the summer of 1903, and especial attention was given during the past summer to finding out how widely it is distributed, and the conditions under which it thrives. As a result

we now know that there are ten or a dozen localities where it is found in large numbers, and that a fairly coarse clean sand and strong currents of clear water are conditions that it generally seeks. The peculiar odor, resembling that of iodine, which is a noticeable feature of the '*Amphioxus* sand' in the Bay of Naples, was not recognized at any of the collecting places examined by us. Incidentally in our dredgings for *Amphioxus,* it was noticed that there are many sandy bottoms and beaches which are inhabited by large numbers of a rather small *Balanoglossus.* The western portion of Castle Harbor contains brain corals (*Meandra*) in great abundance, many of them attaining an enormous size and weight. The rocky shores, overgrown with encrusting sea-weeds, are a favorite browsing place for the great opisthobranch mollusks (*Aplysia*), which the Bermudians call sea-cats (Fig. 27).

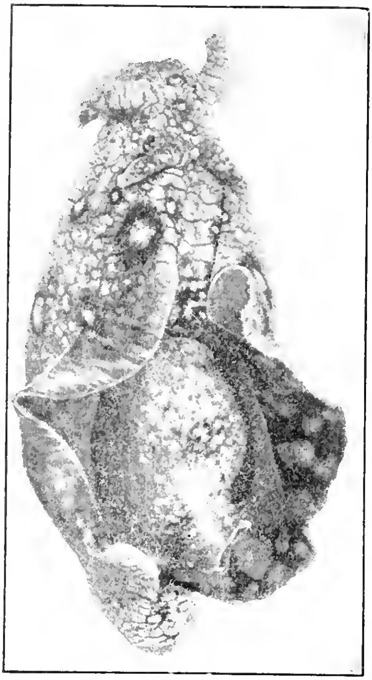


FIG. 27. THE SEA CAT. (*Tethys* [*Aplypia*] *dactylomela*). × 1/3.

Off the south shore, at a distance varying from a few rods to a quarter of a mile, runs a rocky ledge,—a kind of barrier reef,—over which the sea is breaking incessantly. Here and there the rocks take on the form of a huge bowl or crater (Fig. 28), from the rim of which the water pours over after each swell of the sea in a beautiful cascade. These diminutive atolls are known locally as 'the boilers.'

During almost every excursion through the northern lagoon there were encountered extensive patches of floating gulf weed (*Sargassum*), which, I may mention, grows at certain points along the south shore. An examination of the larger masses almost always yielded an abundance of various crabs, bryozoans and nudibranchs, some of the latter being most beautifully colored; frequently the less common fishes, such as the pipe fish (*Syngnathus*) and the grotesque *Antennarius,* were found in these floating islands, evidently their natural home. After protracted strong winds there are thrown upon the beach long windrows of gulf weed, which harbor a variety of the animals that live on the open sea. At such times the Portuguese man-of-war (*Physalia*) is frequently so abundant as to make the beach purple with its floats.

Through the generosity of Captain William E. Meyer, of St. George's, a three-days' trip to the Challenger Bank was arranged for all the members of the station who desired to go. Captain Meyer put at our disposal his seagoing steam tug, the *Gladisfen*, and her crew. Many hauls of the dredge were made and rare corals, crustacea and other invertebrates secured. The edge of the bank is an ideal fisherman's ground, abounding in redsnappers (*Neomœnius aya*) and amber-fish (*Seriola dumerilii*). As might be expected, sharks, too, are found there in abundance.

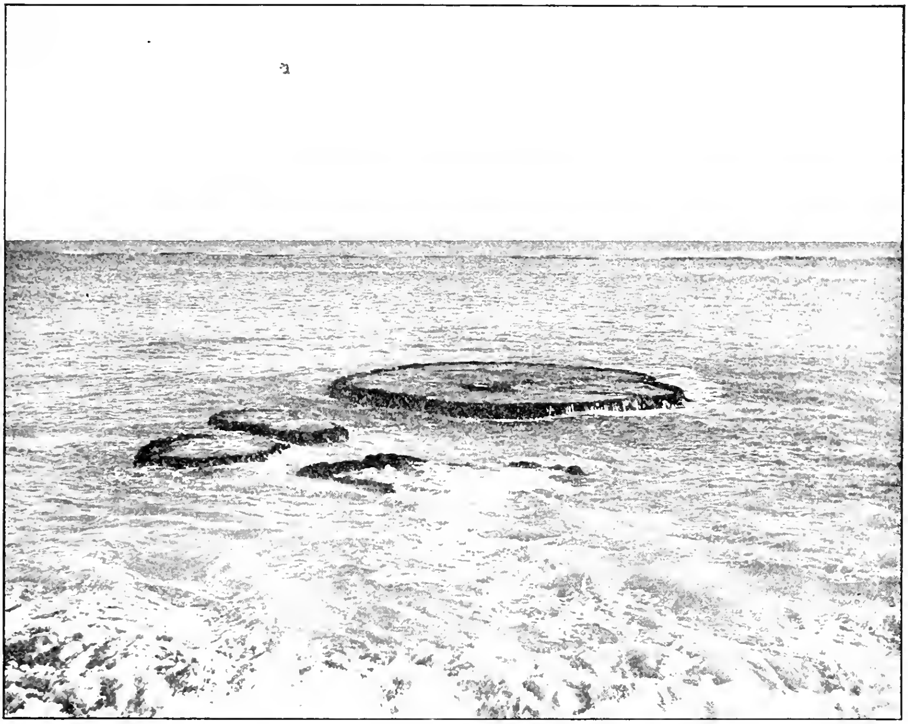


FIG. 28. DIMINUTIVE ATOLLS ('BOILERS') IN THE FOREGROUND; REEF IN THE DISTANCE.

Some of the investigations undertaken by us have already been published as 'Contributions' from the station; others are in press or in course of preparation. Mr. Leon J. Cole's paper on the Pycnogonida (*Proc. Bost. Soc. Nat. Hist.*, Vol. 31) contains an illustrated description and critical discussion of three species, one of which is new. Mr. Addison Gulick has described (*Proc. Acad. Nat. Sci. Phila.*, Vol. 56) some twenty-five species of fossil shells—seven of which are new—from a number of localities, and has pointed out their relationships to shells of Eastern North America and the West

Indies. Notes on birds seen during July and August have been published by Mr. Harold Bowditch (*Amer. Nat.*, Vol. 38). Professor Coe, of Yale University, has published an important paper on one of the very interesting land nemerteans: 'The Anatomy and Development of the Terrestrial Nemertean (*Geonemertes agricola*) of Bermuda' (*Proc. Bost. Soc. Nat. Hist.*, Vol. 31).

Among the other subjects for which material was collected, or upon which investigations were carried on, are the following: The internal parasites of fishes, fossil vertebrates, new marine fishes, shoal-water deposits, land mollusks, insects, myriapods, annelids, land planarians, bryozoans, acalephs and hydroids, foraminifera, diatomaceous earth, marine plants, and the conditions of swamp formation.

During the past summer we had the use of the steam launch *Flora,* owned by Mr. Henry H. Barton, of this city. This launch was larger (about 45 feet over all) and in many ways better than the *Minnow*. This year we were fortunate enough to find at several localities a near relative of *Amphioxus*—the interesting *Asymmetron*, which was discovered several years ago at the Bahamas by Professor Andrews, of Johns Hopkins University. This was first recognized at Bermuda by Mr. Louis Mowbray, of St. George's, who was a member of the station party. It is an interesting fact that, so far as our search extended, *Amphioxus* and *Asymmetron* do not inhabit the same sand banks. The Bermuda *Asymmetron* is much smaller than *Amphioxus* and much more expeditious in burrowing into the sand. *Amphioxus* is remarkably quick in its movements, but *Asymmetron* is quicker. The habits of these two primitive vertebrates, as well as the finer anatomy of their nervous systems and the anatomy and physiology of other organs, were studied by members of the party this year, and will form the basis of special papers to be published later.

In conclusion, I wish to state that the Bermuda government has decided to erect a permanent Aquarium and Biological Station at the Flatts, in accordance with the plans that I have already referred to, and has voted a sum of money (about $20,000) for the undertaking, and a smaller annual sum ($2,000) for its maintenance. It is expected that when the buildings are completed arrangements will be made to have the station open for research throughout the year.

SHORTER ARTICLES AND DISCUSSION.

DOES HIGHER EDUCATION UNFIT WOMEN FOR MOTHERHOOD?

In a very interesting article in the March number of the Popular Science Monthly, Dr. Smith discusses a subject which is vital to the well-being of our nation. The evils which he deplores are real and serious, but they are caused, I would submit, not by excess of *education*, as Dr. Smith has it, but by excess of *luxury* and *indolence*. I am inclined to agree with him that too many of our young people have the higher education bestowed on them, but my reason for thinking so is, not that their intellectuality and spirituality are too highly cultivated and that their ideals are consequently too high, but that they are unworthy of the great boon offered them and, not knowing how to use it aright, are injured instead of benefited: they leave college without having become cultured or intellectual.

There can be no greater mistake than to believe that intellectuality promotes extravagance. Are our college professors and men of science the extravagant members of society? Literature, botany, entomology—even music and art—are inexpensive and healthful pursuits as compared with balls, receptions, dinners and the whole round of social functions.

The most serious enemy to American family life is society—in the narrower meaning of the word. Not only among the wealthier classes do its functions absorb enormous amounts of money and time, but among the middle classes also. Let any of our middle class women who dare, sit down with paper and pencil and write on one side the amount of time given to calls, teas, clubs, golf, dinners and the dress necessary for these functions, and in a column opposite the time given to the intellectual and spiritual welfare of her children. Most of them would not like to show, or look at, the balance sheet. Many of them would say, if they were frank, 'Oh, school takes care of my children's intellects and Sunday-school of their religion.' Too true. And here lies one of the great evils of our modern primary education, to which I will just allude in passing, as it is too vast a subject to introduce here. The school is trying to do mothers' work and necessarily failing, but, owing to the time devoted to this failure, the school is prevented from doing the work which it should and could do and used to do. I will just give one example and pass to a more direct consideration of the subject in hand. For twenty years or more our schools have been trying to instill a love of English literature into their pupils. Can any one who knows the results doubt the failure? They are just launching out on what many of us believe will be a similar futile effort in regard to nature study.

A walk in the woods with a mother or father who has an enthusiasm for botany, entomology or mineralogy is worth ten lessons in the class room or even in the woods with a teacher and forty other children. The book or the poem that mother and child read together because they love it and each other, even if they do not know much about the unities or the functions of the various parts, is more likely to stimulate a love of reading than the most exhaustive and exhausting study in the class room.

Now, how are we to produce mothers who will love this work and hug it to themselves as their greatest blessing?

Certainly, *only by education and culture!* If the college does not give these, reform but do not eliminate it.

Let us glance for a moment at the alternative opened to girls if they do not go to college. Our college girls come mainly, I think, largely at least, from our upper middle classes. Suppose our girl of seventeen or eighteen has just finished her school life, what is she to do? Dr. Smith says: 'Marry.' But really, it seems to me, she will have to wait until she is asked—and meanwhile she will have to occupy herself in some way. The fact of her entering college does not prevent any young man from asking her hand and many a girl leaves college to be married. The question to be solved is simply of how the time intervening between school and marriage is to be passed. If Dr. Smith will study carefully the girls who do not go to college, but who devote themselves to social functions, I think I may venture to predict that his choice of his future daughter-in-law would be more likely to fall upon an earnest college girl than upon one of the social denizens, and that the chances of her having extravagant tastes, indolent habits or poor constitution are less than they would be in the case of the less cultured girl. I believe, but am not sure, that statistics have shown that divorces are much less common among college women than among those who have not been to college.

That a girl's education should not be merely intellectual I readily admit. Sewing, cooking and housework are as much a part of their preparation for their life work as is shop work for our young engineers. But here again we find that mothers are too busy or too indulgent to undertake the task of teaching their daughters and so in the early years the school tries—again with questionable success—to do it for them, and in the later years as a rule it is not done at all—neither for the collegian nor non-collegian.

It is perfectly natural that a girl who has grown up without having done any manual work should not like it when the necessity for it arises, but I doubt very much whether it can be shown that the intellectual girl dislikes it more than the non-intellectual, and our college girl, if she has benefited by her course as she should, has learned the possibility of applying her powers to an uncongenial task and has many more powers to apply than her less educated sister. Were I a hungry husband, I should have more hope of a palatable dinner prepared by a college-bred wife ignorant of cookery, than from one equally ignorant who lacked the college training.

A word as regards the best age for a woman to marry. It seems to me that the chances for marital happiness are best where a woman marries at about 22, an age at which she can have easily finished her college course and at which she is certainly better qualified to judge of the qualities of the man who asks her to marry him than she was four years before. Suppose she marries a man but a few years older than herself, there is plenty of time for them to have a family of five or six children, which is as many as even an energetic mother can well attend to. Probably her demands in the choice of a husband will be more exacting, not as regards wealth, but as regards mind and soul. Could a better stimulus be found for the improvement of our young men?

As to the physical health of our college girls, I feel sure it will compare favorably with that of non-collegians. Neither class is as well as it should be, the reason being, in my judgment, not excessive intellectual exertion but undue excitement and anxiety. The college girl who is chairman of the dramatic association, or the non-college girl who is chairman of the entertainment committee in church, alike suffer from a mental strain which is much more likely to prove injurious

than the steady and peaceful study of Greek, mathematics or anything else. If the college girl insists, as she sometimes does, upon filling the time which should be devoted to study with social amusements and activities and then crams for her examinations at a late hour at night and with a feeling of intense anxiety, she is unquestionably subjecting her health to an undue strain. But this is an *abuse* of the higher education not its *legitimate* pursuit. The girl who steadily pursues her studies as the business of her life, allowing herself reasonable time for exercise and recreation, is most unlikely to be found in the sanitarium among the victims of 'nervous prosperity.' The 'prosperity' shows where these come from—from the ranks of the luxurious and indolent. The best method of preventing egotism, selfishness, and consequently introspection, is to give our boys and girls such intense interests outside of themselves that they have neither time nor inclination for morbid self-study.

I can not go into the question of men's higher education, but should like to say in regard to Dr. Smith's statement about millionaires that I am quite ready to agree that the higher education is not likely to produce them. If a man wants to be a millionaire I think he does wisely to leave school early. But one of the things to be hoped from our higher education is that it will produce in our men nobler ambitions than those of mere money-getting, and in our women the desire for husbands whose aspirations are of a widely different kind.

Our whole notion needs to have the beauty of simplicity impressed upon it. As Emerson says: '*Things* are in the saddle and ride mankind.' What is the remedy? Less culture? No, more! So much that we shall see and taste the higher pleasure that comes from the intellectual and spiritual, and which is always more simple, more wholesome and less expensive than the material enjoyment which it replaces.

OLIVIA R. FERNOW.

THE PROGRESS OF SCIENCE.

THE BIRTH RATE AGAIN.

The Popular Science Monthly has printed several articles on the birth rate, and especially on the relation of higher education to the decreasing size of the family, as the subject appears to be of such consequence that it should be brought within the range of scientific treatment. It is, however, unfortunately true that the statistics are fragmentary and ambiguous, and that the opinions and theories are subject to such large personal equations as to make them almost valueless. It appears to be the case that only about one half of the alumnæ of the eastern colleges for women marry, and that they have on the average only about two children. One hundred alumnæ would thus leave in their places only fifty daughters, twenty-five granddaughters and twelve or thirteen great-granddaughters. But it is not at all certain that this disastrous state of affairs is due to the college education. It is probable that the marriage rate is lowered by the postponement of marriage to an older age and the ease of earning a living otherwise; but there are no available data to prove that the college graduate is less likely to marry than her sister who stays at home. She apparently does not have a smaller family than the Harvard graduate, who marries into the same class. It may be surmised reasonably that the higher education of woman is a minor factor in the decrease of the birth rate, but that the low marriage rate and small birth rate of college alumnæ are primarily due to physiological infertility of the New England stock and to economic infertility of the upper middle classes.

While these matters are being discussed here without an adequate foundation of facts, a very thorough statistical study of the decline in the birth rate of New South Wales has been made by the government statistician, Mr. T. A. Coghlan. It has usually been assumed that the birth rate will be high in a new country, where there is room and work for all comers. This was in fact the case in Australasia until about 1880. The birth rate was then about thirty-eight per thousand inhabitants, and the average number of children in each family was about 5.4. In 1901 the birth rate in New South Wales had fallen to 27.6 and the average number of children in each family to 3.6. Between 1871 and 1880 to every thousand marriages there were 5 384 children, between 1891 and 1900 there may be expected to be 3,636 children. Mr. Coghlan calculates that of the 1,748 unborn children, the loss of 301 may be attributed to postponement of marriage, of 236 to barrenness and of 1,211 to decreased fertility.

Dr. Engelmann has argued in this journal and President Thomas of Bryn Mawr claimed in her address before the St. Louis Congress that a delay in the age of marriage does not appreciably affect the birth rate; but Mr. Coghlan shows that this is an important factor. When the average number of children is 3.6, a woman marrying at the age of twenty may expect to have five children, at the age of twenty-eight three children, at the age of thirty-two two children and at the age. of thirty-seven one child. An unexpected social condition is revealed by the fact that of the 94,708 first births in New South Wales in 1891–1900,

48,271 were of post-nuptial conception, 22,094 of anti-nuptial conception and 24,343 illegitimate. The gradual decline of the birth rate in France and other countries may be attributed plausibly in part at least to physiological infertility, but the sudden change in New South Wales in the course of ten years can not be so explained.

NEW ACADEMIC BUILDINGS.

AMERICAN universities and colleges are more likely to lack men and endowments than buildings. While the salaries of college teachers have remained about stationary and have really become smaller, in view of the increased cost of living and the more complicated social conditions due to larger earnings in other professions, buildings are being continually erected on all sides. And the buildings are certainly welcome. The high school is likely to occupy the most imposing building, except perhaps banks and offices, in each town. The school, college and university express in material form the civic pride of the people somewhat as did formerly the church or cathedral.

We reproduce here illustrations of two of the buildings recently erected for the physical sciences. The Engineering Hall of Washington and Lee University is the gift of Mr. William H. Reid of Chicago. It is of colonial style, in keeping with that of the central university building, of brick with stone trimmings, a hundred feet in length, with an average width of fifty-six feet. The ground floor is used by the department of civil engineering with an electrical laboratory; the sec-

ENGINEERING HALL OF WASHINGTON AND LEE UNIVERSITY.

THE PHYSICAL LABORATORY OF WESLEYAN UNIVERSITY.

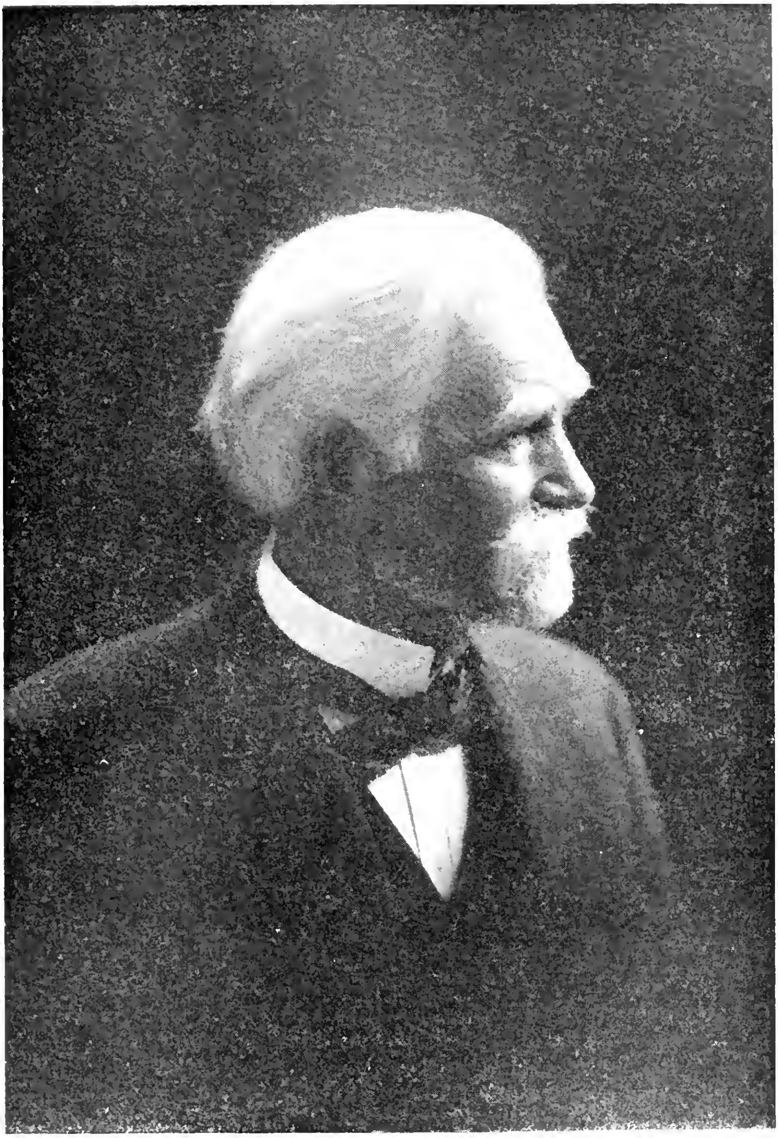
ond floor is exclusively for work in physics; the third floor contains further laboratories for the two departments and drawing rooms. The engineering faculty contains seven professors, with ten other instructors, and provides well-equipped courses in civil engineering, mining engineering and chemistry.

The John Bell Scott Memorial, the physical laboratory of Wesleyan University, was dedicated on December 7, the principal address being made by Dr. Edward B. Rosa, formerly professor of physics at Wesleyan University and now physicist of the National Bureau of Standards. The building is a gift from the late Charles Scott, of Philadelphia, and his son, Charles Scott, who died from disease contracted while serving as chaplain of the U. S. Cruiser *St. Paul*, during the Spanish-American War. The main part of the building is 102x51 feet on the ground plan, and consists of a basement, three stories and an attic. In addition there is an extension of 50x30 feet in the rear which has basement and two stories.

ALBERT BENJAMIN PRESCOTT.

IN the death of Albert Benjamin Prescott, America has lost one of its most honored men of science. Perhaps the chief distinction that can be conferred on an American scientific worker by his colleagues is election to the presidency of the American Association for the Advancement of Science—the number of surviving past presidents is reduced to eighteen by the death of Prescott. Born in 1832, his whole life was associated with the University of Michigan, in the extraordinary development of which his own work was an important factor. He received there the doctorate of medicine in 1864 and was appointed assistant professor of chemistry in 1865. In 1870 he was promoted to a professorship of organic and applied chemistry and was in the same year made director of the School of Pharmacy.

These positions he has since retained as well as the directorship of the Chemical Laboratory, which he assumed in 1884. He served as president of the



ALBERT BENJAMIN PRESCOTT.

American Pharmaceutical Association in 1900, and his contributions to science were largely concerned with the chemistry of drugs, on which he wrote several important books and a large number of special contributions, including several articles in THE POPULAR SCIENCE MONTHLY. He was also the author of excellent text-books on chemistry including 'Qualitative Chemical Analysis,' 1874; 'Outlines of Proximate Organic Analysis,' 1875; 'First Book of Qualitative Chemistry,' 1879, and 'Manual of Organic Analysis,' 1888.

Professor Prescott's death occurred on February 25, when he was in his

Medal Struck in Honor of Captain Scott, Leader of the British Antarctic Expedition.

seventy-fourth year. Memorial services were held in the University of Michigan. Addresses were made by President Angell, Dean Vaughan and Dr. W. J. Herdman, of the medical faculty, and Professor M. L. D'Ooge, of the literary faculty, and resolutions which had been adopted by the various faculties and classes, were read.

SCIENTIFIC ITEMS.

We regret to record the death of Alpheus Spring Packard, professor of zoology and geology at Brown University; of George Bond Howes, Huxley's successor in the chair of zoology at the Royal College of Science, London, and of Adolf Bastian, professor of ethnology at Berlin.

The Royal Geographical Society has struck a special gold medal in honor of Captain Scott, leader of the British Antarctic Expedition, an illustration of which is herewith reproduced.—The British Astronomical Society has conferred its gold medal on Professor Lewis Boss, director of the Dudley Observatory at Albany.—The Prussian Academy of Science has awarded its Helmholtz medal to Professor Ramón y Cajal, professor of neurology at Madrid.

The University of Pennsylvania has conferred the doctorate of science on Dr. R. S. Woodward, president of the Carnegie Institution; and the Johns Hopkins University has conferred the doctorate of laws on Professor William Osler, who is about to assume the regius professorship of medicine, at Oxford.—M. Moissan, of Paris, and Professor Wilhelm Ostwald, of Leipzig, have been elected corresponding members of the Berlin Academy of Sciences.—M. Janssen, director of the observatory at Meudon, and M. Moissan, professor of chemistry at the Sorbonne, have been elected members of the St. Petersburg Academy of Sciences.—Professor Svante A. Arrhenius, of Stockholm, Professor W. F. P. Pfeffer, of Leipzig, and Professor W. Spring, of the University of Liège, have been elected honorary members of the German Chemical Society.

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